MODELLING FOR SIMULTANEOUS SELECTION OF OPTIMAL BUS ROUTES AND THEIR FREQUENCIES – A CASE STUDY FOR AHMEDABAD

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CERTIFICATE

Certified that the work on 'Modelling for Simultaneous Selection of Optimal Bus Routes and Their Frequencies - A Case Study for Ahmedabad', by Umrigar Farokh S. has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

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Umrigar, F.S.

TABLE OF CONTENTS

LIST OF NOTATIONS

AVERSP	-	Average speed of the bus (Kmph).
$(BUSTRP)_r$	-	Number of bus trips for a route r.
CAP	-	Maximum number of passenger that can be accomodated in a bus.
DIST(i, j)	-	Internodal distance between the nodes i and j.
FLOW(i, j)	-	Flow on a link connecting the nodes i and j.
$(FREQ)_r$	-	Frequency on route r.
$(INCOME)_i$	-	Daily average traffic income in paise for a route i.
JFLOW(i, j)	-	Flow of passengers between the O-D pair i-j.
KMCOST	-	Operating cost of a vehicle (60 seat capacity) per vehicle kilometre.
$(LF)_i$	-	Average load factor for route i.
$(LKFLOW)_i$	-	Flow of passengers in unit time on link i.
$(LKFLOW^*)_i$	-	Flow obtained by using T_i^* as the link time.
$(LNGTH)_i$	-	Length of the link i.
$(LOT)_r$	-	Lay over time at the destination of a route r.
$(LT)_i$	-	Total link time of the i^{th} link.
$(MAXF)_i$	-	Maximum fare in paise for a route i.
$(MAXFRE)_r$	-	Maximum frequency of route r.
$(MAXTFL)_p$	-	Maximum value of the turning flow for the p^{th} turning movement.

M1	-	Number of inequality constraints in the LP formulation.
M2	-	Number of equality constraints in the LP formulation.
NLINKS	-	Number of links in a route.
$(NOBUS)_i$	-	Number of bus trips to be made in a unit time on a link i.
NONODS	-	Number of nodes (stops) in a route.
$(NOTRAN)_{pr}$	-	Number of transfers saved for p^{th} turning flow.
$(NOTRN)_p$	-	Number of transfers saved for p^{th} turning movement.
NR	-	Number of routes in a network.
$(NR)_k$	-	Number of interested routes touching the stop k of a route.
$(NUMP)_r$	-	Number of passengers served by a bus trip of route r in one direction.
OPF	-	Operating fleet size for the bus transit network.
OT	-	Operating time i.e. the number of hours for which the bus service is provided in a day.
$(PROB)_k$	-	Probability of a passenger to get down at the stop k of a route.

$(RT)_{ir}$	-	Riding time on link i traversed by route r.
$(RTTIME)_r$	-	Round trip time on a route r.
SD(i, j)	-	Shortest distance between the origin i and destination j.
$(ST)_j$	-	Service time (dwelling time) at the j^{th} stop of a route.
T_i	-	Revised time on link i considering the riding time of passenger and the vehicle time for the first iteration.
T_i^*	-	Revised time on link i considering the riding time of passenger and the vehicle time for the subsequent iterations.
TLT	-	Total time of the network.
$(TRIPS)_i$	-	Number of scheduled bus trips in a day for route i.
$(TRIPSG)_i$	-	Number of trips generated at the stop i.
$(TRL)_r$	-	Total route length of route r in Kms.
$(TRT)_r$	-	Total riding time on route r.
$(TST)_r$	-	Total service time in one direction for route r.
$(TT)_r$	-	Total travel time in one direction for route r.
TTFR	-	Number of turning flows along a route.
$(TTRAN)_r$	-	Total number of transfers saved by a route r.

$(TURNFL)_{lk}$ - Number of passengers going directly from link l to link k or vice versa in a day.

TTF - Total number turning flows (movements) in a network.

VT - Value of riding time in Rs./hr.

$(VOLP1)_i$ - Average link volume on route i by load factor criterion.

$(VOLP2)_i$ - Average link volume on route i by maximum fare criterion.

W - Weight for the value of a vehicle time compared to a riding time of a passenger.

Z - The objective function for the LP problem.

Z_1 - The objective function for the problem of concentration of flow.

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

SYNOPSIS

A few major limitations of the past research in the area of routing and scheduling of the bus transit system are: (i) the generation of routes and scheduling of vehicle in the network is done sequentially, (ii) evaluation of alternative paths of a route is carried out independent of the already accepted routes for the network.

In this study, an attempt has been made to develop a method such that the selection of the routes and the assignment of frequencies is done simultaneously for the bus transit system. The method has been developed in four stages: (i) to generate a trip distribution matrix, (ii) to concentrate the flow of passengers on the road network such that the sum of passenger-riding-time-cost and operation cost is minimized, (iii) to generate a large set of all possible routes that satisfy the various constraints, (iv) to select routes and their frequencies so that number of transfers saved on the network is maximized. Heuristics have been used for the concentration of the flow and generation of the routes while Linear Programming (LP) has been used to select routes and their frequencies.

A method has been suggested to estimate trip distribution matrix by using generally available traffic data of the existing routes for the city bus network.

The flow of passengers on the various links of the network is concentrated such that the sum of passenger-riding-time-cost and operation cost of the vehicles is minimized. An heuristic algorithm has been developed for concentrating the flow. The relationship between the number of bus trips and the flow of passengers on a link has also been derived. The starting network consists of all the links where vehicles could possibly travel. Passenger flows have been systematically concentrated by eliminating the links, in stages such that the total cost is minimized.

For a given desired travel matrix, a large set of all possible routes between different O-D pairs is generated using an heuristic procedure. The generated routes satisfy the practical constraints of length and the deviation from the shortest path.

The total number of transfers saved on a route is determined based on the size of the turning movements along the route and the estimated number of bus trips on the links. For a given operating fleet size the

simultaneous selection of routes and their frequencies is done by Linear Programming such that the total number of transfers saved on the network is maximized.

Ahmedabad city has been chosen for the case study for structuring of the bus transit network. The optimal set of routes and their frequencies have been estimated for three operating fleet sizes.

1 INTRODUCTION

1.1 General

The ability of cities to expand in size depends heavily upon the available means of public transportation. Originally, travel on foot, or by crude land-based means, severely limited the ability of cities to develop. With the industrial revolution, public transportation systems that would move large numbers of people came into existence, due to the rapid growth of cities and the separation of home and work place. So, urbanization is a worldwide phenomenon. The urban population is growing at a rate of 4 to 7 percent a year. In some cities of India, the growth is as high as 12 percent.

The two most important modes of public transportation particularly for the cities of the developing country like India are bus transit system and commuter rail system. Each mode has a role to play in furnishing transit services, and the task of the engineer and the planner is to integrate each into a coherent system of public transportation.

The bus transit is the most prevalent mode and carries over 70 percent of all transit travel. Its inherent advantage is the ability to be routed along any street or highway, and for this reason buses serve many land-use

densities and urban configurations. As the 'work-horse' of public transit, the bus lacks glamour, but its attributes of reliability, availability, flexibility and economy indicate that it will remain as the most popular mode of public transportation for years to come.

The urban transportation system is comprised of an intricate and complex arrangement of various public transportation modes, and there are many elements and factors that should be considered in assuring that each mode operates harmoniously to produce a high level of transit service. As stated earlier, 70 percent of all transit travel is taken by bus system, it is imperative to plan and operate the existing bus transit systems in most effective way with the available resources.

1.2 Statement of the Problem

In spite of the advantages of bus transit system, bus route configurations in most cities have virtually remained unchanged. Only in the recent years the importance of a large-scale re-evaluation of bus routes has been realized. One of the main reasons for the inefficiency of the bus transit system is the lack of systematic approach in designing the transit network.

The problems that are normally encountered by a bus transport management are economy in operation, reliable and adequate level of service to the users. To solve these problems it is necessary to investigate the following:

(i) Structuring of the routes in order to meet the demand in an effective manner.

(ii) Determination of the minimum fleet size for a specified level of service for the system.

(iii) Determination of the schedules to minimize the overall system costs.

Traditionally, bus networks were designed on the basis of the planners' own experience. In addition, other approaches that have been attempted are mathematical programming, heuristic searching and simulation. The approach of formulating the network design as a problem of mathematical programming has not been capable of dealing with networks of realistic size due to the limitations of computer capacity. Most of the heuristic searching approaches, on the other hand, also fall short of becoming a comprehensive framework for network design due to the fact that they are originally developed primarily as frameworks for route selection rather than for network development. Simulation of the transit system, though a powerful tool, has been restricted mostly to

individual routes or small size transit networks. Following section highlights some of the pertient research in this direction.

1.3 Review of Literature

Lampkin and Saalmans (1967) analyzed the routing and scheduling of a city bus service by first designing a route network and then allocate frequencies (interarrival times) to these routes. The major component of the operating cost was taken as the cost of crews, so minimizing total travel time subject to a given crew strength is equivalent to minimizing total travel time subject to a fixed level of profit or loss.

The total travel time for the network was calculated,taking the routes to be fixed for the three cases:

(i) When the time to walk is greater than the bus time plus interarrival time of most frequent route joining the nodes. If only one route joins the origin node and destination node, then average journey time is the sum of bus time and half of the interarrival time. If more than one bus routes join terminating nodes, the proportion of passengers using the different routes were found out and the average bus time was calculated. The average journey time was taken as the sum of the average waiting time

and average bus time.

(ii) The second case, they considered was that passenger waits if the sum of the bus journey time and time to the next bus is less than or equal to walking time for his destination, otherwise he walks.

(iii) For the third case, they considered only the walking times by different route alternatives and the minimum average journey time was found out.

The objective of minimizing the total travel time was achieved by a modified random search procedure, in which an initial guessed solution started the procedure and thereafter new value of frequencies were produced by random perturbations from the best frequencies found to date.

An heuristic algorithm was developed for structuring a route network. It consists of producing an initial skeleton route of four nodes and then inserting nodes one by one until a complete route is obtained. The demand met by this route was eliminated from the travel matrix. The other routes were obtained for all significant demands left over. The best node to insert in a given gap in a skleton is a node which improves the value of the objective function, consisting of maximizing passenger-kilometres

with penalty for excessive meandering.

The limitations of their study are that their approach does not consider the previously accepted routes while generating the subsequent routes so the effect of the interaction of various routes is not taken into consideration.

Hsu and Surti (1975) gave a method of optimal bus network design based on nodal demands. Bus routes were first classified into several categories (i.e. corridor, activity, transfer, residential) each having a different developmental priority. After the number of bus routes to be included in each stage was determined, the origins and the destinations of potential routes were identified. Optimal alinement connecting the route origin and destination was subsequently located. The separate consideration of the route origin-destination and route alinement was made possible by the relationship between the route performance and the attractiveness of route origin and destination. Their method differs from that of Lampkin and Saalmans (1967) in the criterion for evaluating route alternatives. Their approach of maximizing passenger per kilometer over the route alternatives seems better than maximizing passenger-kilometers used by Lampkin and Saalmans. The latter approach will give the same priority to the

alternative with longer length and less passengers as given to the one with shorter length and more passengers.

Last and Leak (1976) gave a computer based model ('TRANSEPT') that evaluates bus networks, i.e. it predicts the trip makers who are expected on a network, works out the implications of those trip-makers for each route, and for the network as a whole. They carried out a review of the bus system then in operation by performing the following tasks:

(i) Structuring the bus network so as to identify potential journeys within it.

(ii) Predicting the number of trips which will use these potential journeys.

(iii) Implications of these trip-makers (patronage) for bus loadings and subsequent evaluations.

This study provided the insight into operation of network at four levels, viz. operational, financial, user and modal split.

Dhingra (1980) designed the routing and scheduling of a city bus service by considering the following taks:

(a) to design the optimum route network for a given travel demand;

(b) to design the optimum fleet size;

(c) to study the effect of variation in total fleet size on waiting time, load factors and other performance measures;

(d) to design the optimum schedule.

An heuristic approach was taken to design the route network. It consists of following steps:

(i) Given the O - D trip matrix the major generators were identified.

(ii) The routes between the major traffic generators were identified using shortest path trees.

(iii) The travel demand met at the nodes covered by the above routes was determined.

(iv) If the demand at the uncovered nodes is significant, additional shortest routes were indentified.

(v) He assumed that the additional distance of any route alternative thus generated should not be greater than two-third of the original shortest routes.

He evaluated the route alternatives on the following three criteria:

(a) Passenger-kilometers criterion maximizes the passenger-kilometers over all the route alternatives.

This criterion does not discern the difference between a longer route with low passenger density and a shorter route with high passenger density.

(b) Average link density criterion maximizes the average link density over the route alternatives. This criterion favours the alternative with more passenger density and the shorter length of the route.

(c) Route utilization coefficient criterion maximizes the route utilization coefficient over route alternatives.

After fixing the routes, he found out the fleet size and designed a schedule to meet the travel demand in an optimal way, using simulation model as a tool. This simulation model simulates at a microlevel, the flow of passengers and vehicles in a given network. The salient features of the simulation model are as follows:

(a) It simultaneously simulates the flow of passengers on all the nodes of the network and the movement of the vehicles on all the routes thereby taking into account the interaction effects of overlapping, crossing, merging and diverging routes.

(b) Input to the model is average passenger arriving volume, their probability distribution, relationships

for the boarding, alighting and booking times of passengers at each station, internodal distances, running times and capacities of the vehicles. In order to incorporate the interaction of the overlapping routes in the network, the station scanning technique is used.

(c) The output from the simulation model consists of three parts; the output for each of the stations, the routes and the network. At a station, the output related to passengers consists of the waiting time, queue length and service times. For a route, the simulation results are in the form trip times, vacancy/load factors, waiting times, number of passengers processed, the route speed and passenger-kilometers operated. For the network, the results are in the form of average queue length, the passengers processed for a period, the vehicle kilometers operated, waiting time and load factor.

The limitations of Dhingra's study are as follows:

(i) Routes are designed based on travel demand and are assumed to be independent of schedules.

(ii) No studies have been conducted to establish delay cost per hour. It has been calculated assuming the average income and working hours per month of the bus transit users.

(iii) The use of a vehicle over multiple routes is not covered.

(iv) Crew roastering and runcutting operations have not been covered.

(v) The problem does not cover the multiobjective analysis but two conflicting costs of delay and operation are considered.

The studies by Lampkin and Saalmans (1967) and Hsu and Surti (1975) attempt towards total network design. But none of the above models consider the previously accepted routes.

1.4 Objectives of the Study

The management of the public transportation company has got limited variables to play with, due to political and social influence. In India, the normal situation is that the fare is not decided strictly in accordance with the operator cost but it is a compromise between operators' cost and the passengers' ability to pay. Within these limits the management may choose routes and frequencies freely. So, the objective should be to maximize social utility with the restrictions on operating cost and minimum travel standard.

The literature (Section 1.3) for the various models of bus transit planning indicate that the

generation of routes and the scheduling of vehicles in the network is done sequentially. The routes are first generated, one at a time based on the given desired travel matrix. A route is evaluated independent of the routes already accepted for the network. Evaluation by such an approach does not fully consider the interactions in the transit routes. The scheduling of the vehicles on the routes is done after all the routes in the network have been fixed.

The objective of the study is to develop a method such that the selection of the routes and the assignment of the frequencies is done simultaneously for the bus transit system. The method should be applicable to the real world large size bus networks. The method suggested is a combination of heuristic search and programming models. The method first considers all the links on which the vehicle possibly could travel. The flow of passengers is then systematically concentrated by eliminating links so that the total cost (i.e. passenger-riding-time-cost + operation cost) is minimized. A large set of possible routes, which satisfies the various requirements, is generated. The selection of the routes and their frequencies is done using the programming model so that the number of transfers saved on the network is maximized.

1.5 The Extent and Scope of the Study

This study aims at the structuring of bus transit network in which selection of routes and assignment of frequencies is done simultaneously for the fixed O - D matrix. The approach suggested in the study uses heuristic search and mathematical programming models. The salient features of this study are:

(i) Ahmedabad city has been chosen for the case study and the system of models developed have been used for structuring of the transit network and assignment of frequencies to the routes.

(ii) Due to nonavailability of the bus trip distribution matrix for the cities in India, a method has been suggested to generate the same by using generally available traffic data of the existing routes in the network.

(iii) The computer programmes for the system of models have been developed and can be applied to any transit network.

The problem under investigation is limited due to constraints on the availability of data and time. Some of the limitations are as follows:

(a) Structuring of routes and the assignment of frequencies is done for a given desired trip

matrix and does not evaluate the stochastic variations in the travel demand.

(b) The frequencies (number of bus trips) are assigned for the full day. The variations of the headways over the day have not been investigated.

(c) Operator cost and passenger-riding-time-cost have been considered in terms of time by estimating their weights.

1.6 Organisation of the Report

The study is reported in the following sequence:

(i) The models for generating a fixed O - D matrix, concentration of passenger flow, systematic route generation and selection of routes and their frequencies, are developed (Chapter 2) .

(ii) Description about the case, traffic data requirements and analysis of data are given. Experiments for limited range (670 to 790) of fleet size are done to study its effect on the optimal number of routes and the number of transfers saved. The optimal set of routes with their frequencies for the case problem is presented. The results are analyzed to establish the relationships between the variables of interest. The relationships between the fleet

size and number of transfers saved; fleet size and optimal number of routes and fleet size and average route length are presented (Chapter 3).

(iii) Study is summarized, conclusions are drawn and suggestions are made for the future investigation (Chapter 4).

2 DEVELOPMENT OF THE MODEL

2.1 Introduction

Today's transit planning, particularly in developing countries like India, is inefficient due to the lack of systematic approach in designing the networks. Different approaches fail to provide planners with a handy and powerful tool in the following aspects: the experience based approach is basically an intuitive approach and cannot promise any solution in the optimal sense; the mathematical programming approach is theoretically rigorous but fails to handle any network of realistic size; heuristic search algorithms are designed primarily for the microscopic problem of route-selection rather than the macroscopic task of network design. In addition, simulation of the transit system though a powerful tool has been restricted mostly to individual routes or small size transit networks.

Theoretically, it can be seen that the routing and scheduling processes for a bus transit network interact and a global objective function should be formulated in devising solutions for the problems. However, in actual practice, it is not possible to formulate the problem structure in this way. Usually this class of problems can be tackled recursively by dividing the original problem

into problems involving subsystems which can be made tractable.

The problem of automatically generating a good urban route system has been treated by a few authors as reviewed in Chapter 1. A common method is to sequentially generate and evaluate routes without seriously reconsidering previously accepted routes. In spite of this, only relatively small systems have been analyzed probably due to excessive computation time. The purpose of this study is to propose a method such that the selection of the routes and the assignment of the frequencies is done simultaneously for the bus transit system. The method should be applicable to the real world large size bus networks and involves lesser computation time. The method suggested is a combination of heuristic search and programming models.

2.2 Overview of the Model

The proposed method consists of the following steps:

(i) Generate a fixed desire travel matrix (i.e. a matrix that gives a good idea of the potential demand in every origin-destination relation).

(ii) Generate a network which consists of all the links on which the vehicle possibly could travel.

(iii) The flow of passengers is then systematically concentrated by eliminating links so that the total cost (i.e. riding time cost + operation cost)is minimized .

(iv) A large set of possible routes, which satisfy the various requirements, are generated.

(v) The total number of turning movements for the network are identified and the number of transfers saved for each turning flow along the route and for all the routes, are found out.

(vi) The selection of the routes and their frequencies is done using the Linear Programming (LP) model so that the number of transfers saved on the network is maximized.

2.3 Origin - Destination Matrix

The model needs the volume of the distribution of trips between various nodes. In absence of origin-destination data for the trip distribution, the following procedure can be applied to the existing bus route network for obtaining the desire travel matrix. The steps in the procedure are as follows:

(i) Average link volume on each route during the day is obtained from load factor and maximum fare criteria.

(ii) Each stop on a route is assigned a weight depending upon the importance of the stop quantitatively measured in terms of number of routes touching the stop. These weights are used to define the probability of trip generation on each stop of a route.

(iii) The generated trips at a stop are then distributed to other stops of the route using the relative weights of the different stops.

(iv) The trip-distribution matrix for the network is obtained by combining the distribution of all the routes. Fig. 2.1 shows the procedure for generating O - D matrix.

2.4 Riding Time on Links

For the concentration of link flows on the network, the riding times on various links need to be estimated. Generally, travel time of the bus on a route is available. The total riding time of a route r i.e. $(TRT)_r$ is estimated using the following relationship:

$$(TRT)_r = (TT)_r - (TST)_r \tag{2.1}$$

where

$$(TST)_r = \sum_{j=1}^{NONODS-1} (ST)_j \tag{2.2}$$

where

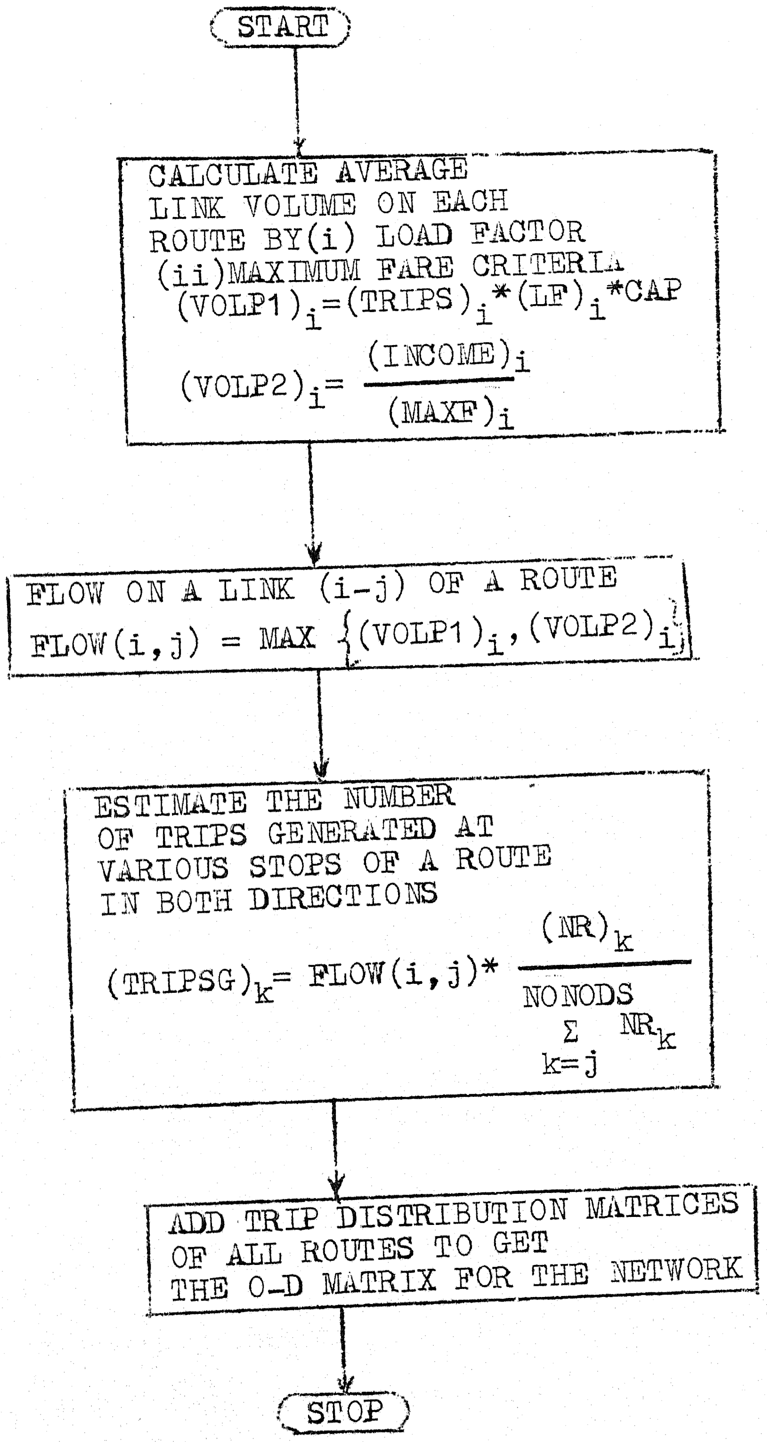


FIG. 2.1 : PROCEDURE FOR GENERATING O-D MATRIX

$(TRT)_r$ = Total riding time on route r

$(TT)_r$ = Total travel time in one direction for route r

$(TST)_r$ = Total service time in one direction for route r

$(ST)_j$ = Service time at the j $\underset{..}{\underline{th}}$ stop of the route.

After estimating the total service time for a route in one direction, the total riding time $(TRT)_r$ is calculated by Eqn. 2.1. The riding time on link i traversed by route r is calculated by the following relation:

$$(RT)_{ir} = (TRT)_r * \frac{(LNGTH)_i}{\sum_{i=1}^{NLINKS} (LNGTH)_i} \qquad (2.3)$$

where

$(RT)_{ir}$ = Riding time on link i traversed by route r.

$(LNGTH)_i$ = Length of link i.

NLINKS = Number of links in a route.

If there is a variation in riding time obtained for links served by the number of routes, then the average value of the riding time is used.

2.5 Preparation of the Road Network

For the concentration of flow, a starting network, consisting of all the links where vehicles could possibly

travel is needed. The length of the link and the riding time on the link can be found out from existing route characteristics like length, travel time, and service time for the route. The riding time on the links which are added to the existing route network can be found out by considering the average speed of the bus obtained from the data of the existing system.

2.6 Model for Concentration of Passenger Flow

2.6.1 General

The model estimates where the passengers are expected to travel in the optimal route system. From the passengers point of view, they would like to travel by their shortest paths, which would imply a very dispersed route network with low vehicle utilization and many vehicle hours. On the other extreme if the links, on which there is negligible or less flow, are deleted then the passengers will have to make substantial detours from their shortest paths, with increased riding time for the passengers. To get a reasonable compromise between these two extremes the sum of operation cost and passenger riding time cost can be minimized for a fixed desired O - D matrix.

Let RT_i be the riding time on link i and $((LKFLOW)_i)$ is the passenger flow in unit time on link i

then the total riding time for all the passengers is $\sum_i (RT_i)\ ((LKFLOW)_i)$ and the total vehicle time for the network is $\sum_i (RT_i)(NOBUS)_i$ where $(NOBUS)_i$ is the number of bus trips to be made in a unit time on a link i. The objective function is:minimize (passenger-riding-time cost+ operation cost) i.e.

Minimize

$$Z_1 = (\sum_i (RT_i)(LKFLOW)_i + \sum_i RT_i (NOBUS)_i . W) \qquad (2.4)$$

subject to all demand of travel matrix is satisfied.

where

W = value of vehicle time compared to riding time of passenger.

The parameters $(NOBUS)_i$ and W are to be estimated using the available data of the bus transit system.

Estimation of Parameters:

(a) Number of bus trips on a link

The number of trips to be made in a unit time on a link i.e. $((NOBUS)_i)$ depends upon the passenger flow on that link i.e. $((LKFLOW)_i)$. Some studies (Scott, 1969; Rea, 1971) indicate that $(NOBUS)_i$ is directly proportional to the square root of passengers on a link. If such relationship for a particular city or country is not available, then using the data of average link flow and

number of bus trips, regression analysis can be carried out to get the following relationship:

$$(NOBUS)_i = A((LKFLOW)_i)^B \quad (2.5)$$

where A and B are the constants to be estimated.

(b) Value of vehicle time compared to riding time of passengers (W)

W is calculated using the following relationship:

$$W = (BUSKMH) * (KMCOST)/(VT) \quad (2.6)$$

where

BUSKMH = Kilometers travelled by a bus in one hour.

KMCOST = Operating cost of a vehicle(bus) per bus kilometer.

VT = Value of riding time of the passenger.

The operating cost of a vehicle per bus kilometer is found out by taking into consideration the heads like salary and allowances, fuel and lubricants, repairs and spare parts, overheads, depreciation and head quarter charges.

The value of riding time of the passenger can be found out by assuming an average income of captive user and value for unit time is calculated.

The value of BUSKMH can be obtained from the existing data of speeds of the bus on various sections of

the networks. Generally the speed in the central business district area is comparatively less than the outlying and peripheral areas of the city. So the average speed is taken from the existing speeds data.

2.6.2 Analysis of the Objective Function

The objective function defined in Eqn. 2.4 can be written as follows by substituting $((NOBUS))_i = A(LKFLOW)_i^B$

$$\text{Minimize } Z_1 = \sum_i (RT_i)(LKFLOW)_i + \sum_i (RT)_i A.(LKFLOW)_i^B.W$$

$$Z_1 = \sum_i (LKFLOW)_i \left[(RT)_i \left(1 + \frac{(W).(A)}{(LKFLOW)_i^{1-B}}\right) \right] \qquad (2.7)$$

$$= \sum_i (LKFLOW)_i \, . \, T_i$$

where

$$T_i = (RT)_i \left(1 + \frac{(W).(A)}{(LKFLOW)_i^{1-B}} \right) \qquad (2.8)$$

The objective function Z_1 (Eqn. 2.4) is nonlinear. When a network consists of all the possible links where vehicles could travel, the passengers will travel along their shortest paths with the result that the first component of the equation related to passengers' cost namely $\sum_i (RT_i)(LKFLOW_i)$ will be minimum, but the second component related to the operating cost of the vehicle namely $\sum_i (RT_i)(LKFLOW)_i^B (A).(W)$ will be more. So to get a compromise between these two

components, the sum of the passenger-riding-time-cost and the operating cost should be minimized.

When analyzing vehicular-traffic, the increase in total cost on a link, due to one more vehicle is an increasing function as the flow increases, the total riding time on the link also increases. In the bus transit system (Fig. 2.2) as the flow increases, the change in cost as related to passenger flows on a link i.e. ($(PTCOST)_i$) reduces for a unit change of flow i.e. ($(LKFLOW)_i$). So by increasing or concentrating the flow on link i, the total cost can be reduced.

To achieve the objective of minimizing the total cost (Eqn. 2.7), various alternative networks of links are evaluated and that network of links is selected which gives the minimum total cost. In case where it is difficult to estimate the value of time, then time values can be directly taken as cost units.

The starting network consists of all the links on which vehicle possibly could travel. The problem of concentrating the flows can then be seen as one of eliminating the links from this finemeshed network. The other way of looking at a problem is to reduce flow conentration by adding possible links to the minimal spanning tree. These

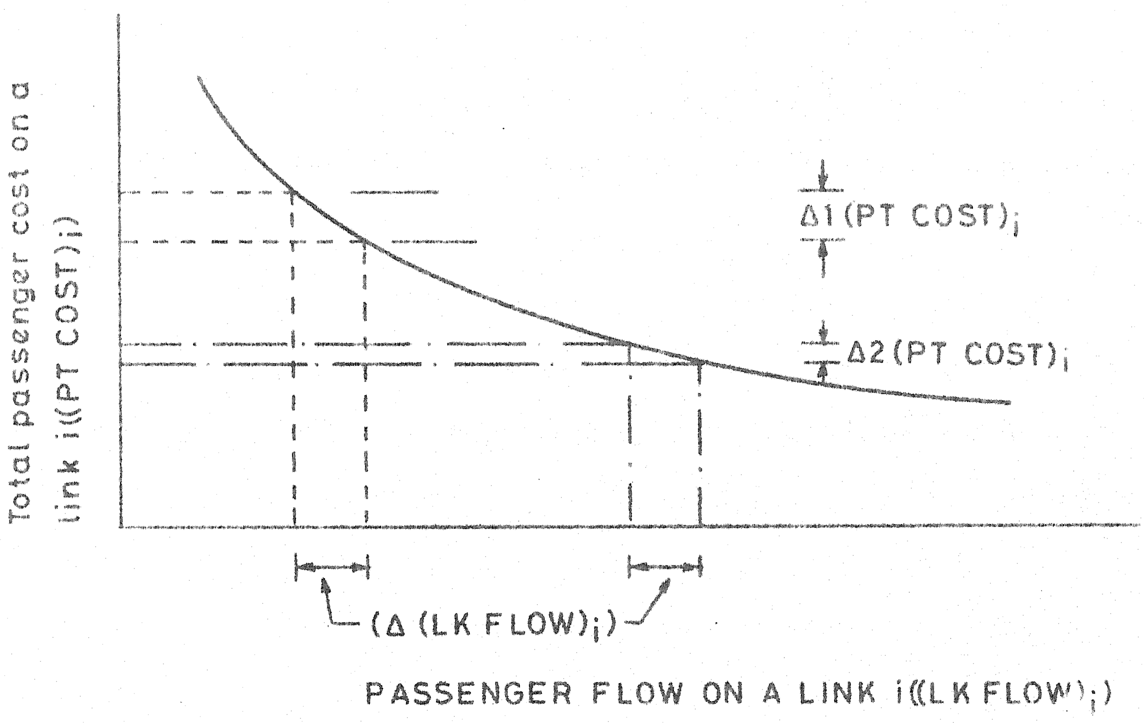


FIG.2.2 RELATIONSHIP BETWEEN TOTAL PASSENGER COST AND PASSENGER FLOW FOR BUS TRANSIT SYSTEM.

two ways of looking at the problem results into the two different approaches to solve it, backward or forward. Scott (1969) has tested both the approaches, and concludes that 'on all counts the backward algorithm would appear to give better results than the forward algorithm'. So this study also choses a backward approach, thus starting from the fine-meshed network and proceed towards a coarse-meshed network.

For minimizing the nonlinear function, the objective function and the feasible region must both be convex in order to be sure that a local minimum is also a global minimum. But for the problem under consideration, the objective function and the feasible region are not both convex. So based on Kuhn-Tucker theorem, algorithmic procedure based on the local properties of the problem, is derived to produce a local stationary point which may neither globally maximum nor minimum. The steps in the algorithmic procedure are as follows(Hasselstrom,1979):

(i) The shortest paths for all the origin-destination pairs are obtained. In the first iteration, only riding time (RT_i) is considered but in subsequent iterations the sum of riding and vehicle time (as revised in the subsequent steps) i.e. T_i^* is used. Using the shortest paths, all the link

flows ($(LKFLOW)_i$) are estimated for the given O - D matrix.

(ii) The time (T_i) to traverse a link i is revised (T_i^*) based on the link flow ($(LKFLOW)_i$) using the following relationship:

$$T_i^* = ((RT_i)) * \left(1 + \frac{(W).(A)}{2(LKFLOW)_i^{1-B}}\right) \qquad (2.9)$$

(iii) The revised time T_i obtained in step (ii) is used to find the shortest paths for all the O - D pairs and revised value of the link flow ($(LKFLOW)_i^*$) is obtained.

(iv) Compute the total link time i.e. $LT_i = (T_i)^* \ (LKFLOW)_i^*$ and total time for the network i.e.

$$TLT = \sum_i (T_i)^* \ ((LKFLOW)_i^*) .$$

(v) If any of the link time (i.e. LT_i) or total link time (TLT) gets changed in step (iv) then the procedure is repeated starting with step (ii) otherwise it is stopped. Fig. 2.3 shows the above procedure.

2.7 Procedure for Generation of Routes

A large set of all possible routes be generated and then optimal ones alongwith their frequencies be

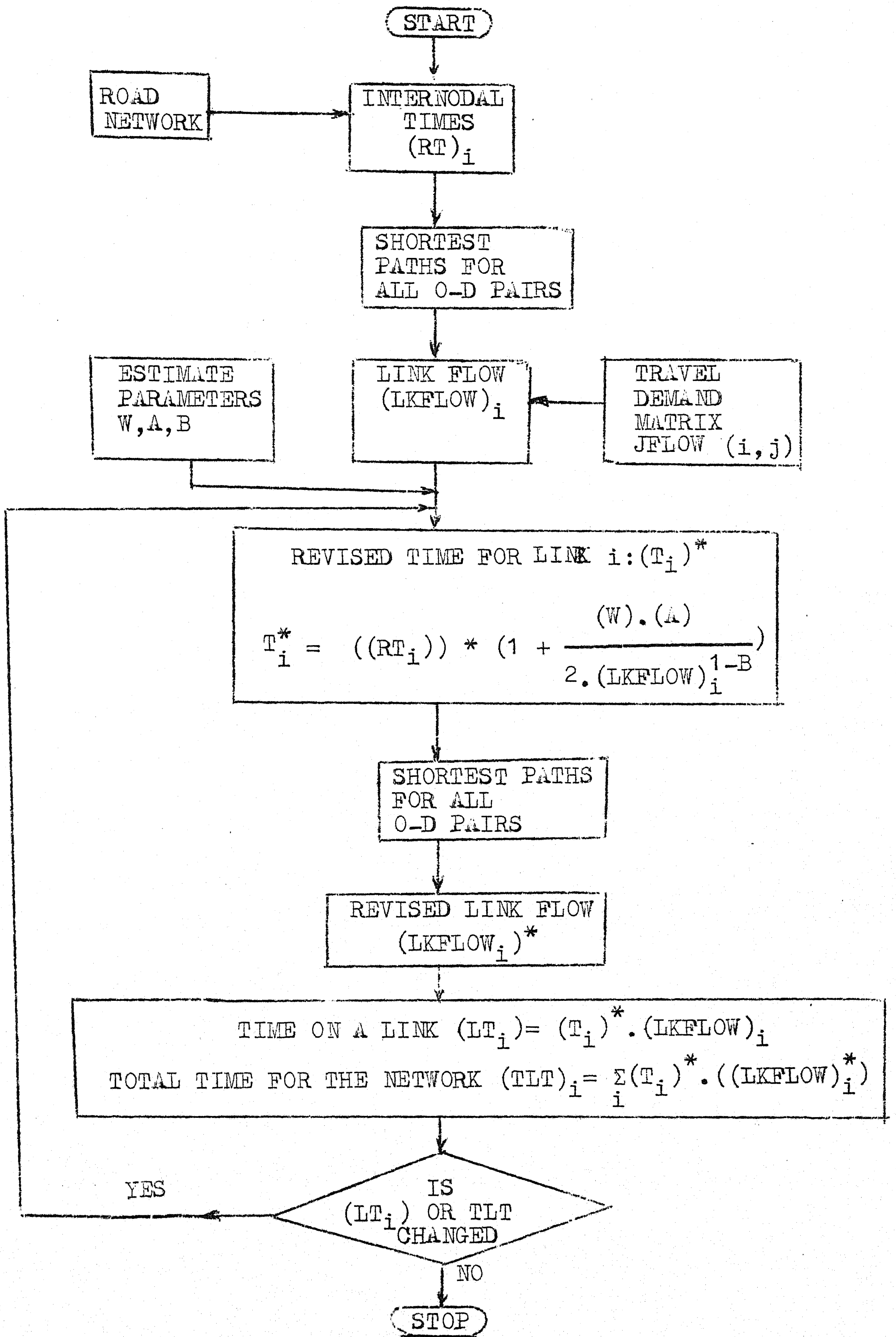


FIG. 2.3 : PROCEDURE FOR CONCENTRATING PASSENGER FLOW

selected using Linear Programming, so that the number of transfers saved is maximized. For a large network it is not necessary to generate a route between every O - D pair, otherwise some nonfeasible routes will be generated. So, a heuristic procedure is developed to generate sufficiently large number of routes which satisfy the following requirements:

(i) The length of the route should not be less than the minimum length specified for the particular problem under study.

(ii) The path of the route between two terminating stations should not meander excessively from the shortest path.

(iii) There should not be any backtracking on the route.

To decide the terminating stations it is desirable that the major generation should have the routes through them. The routes be also generated from other stations so as to satisfy the entire O - D matrix. As discussed in Chapter 1 (Section 1.3) the various models of bus transit planning indicate that firstly the routes between the major generators are fixed but the difficulty is that of satisfying the various requirements of a route in an optimal way. In this method the paths of routes between closer terminals are first decided and then expanded for the distant terminals.

Already developed paths are of great significance in location of the paths of the routes between the distant terminals. In a nutshell, the procedure is as follows:

(i) Routes are first generated for the O - D pair which have direct links.

(ii) The O - D pairs which are not directly connected are divided into various groups according to shortest distance between them. The generation of routes is done by first analyzing closer O - D pairs and then expanding for distant O - D pairs.

(iii) The node (K) is inserted between the O - D pair (i-j) such that the distance of the selected path i-k-j does not exceed twice the shortest distance between i and j.

(iv) All the routes generated are used to find if any traffic demand for a O - D pair is left out. If it is so, new routes are generated between these O - D pairs. Fig. 2.4 shows the above procedure.

2.8 Transfers Saved on a Route

When the route terminates at the node, the passengers destined for some other node have to transfer at this node. If the route (Fig. 2.5) on link l goes to the next link k, then the flow of those passengers who travelled on both the

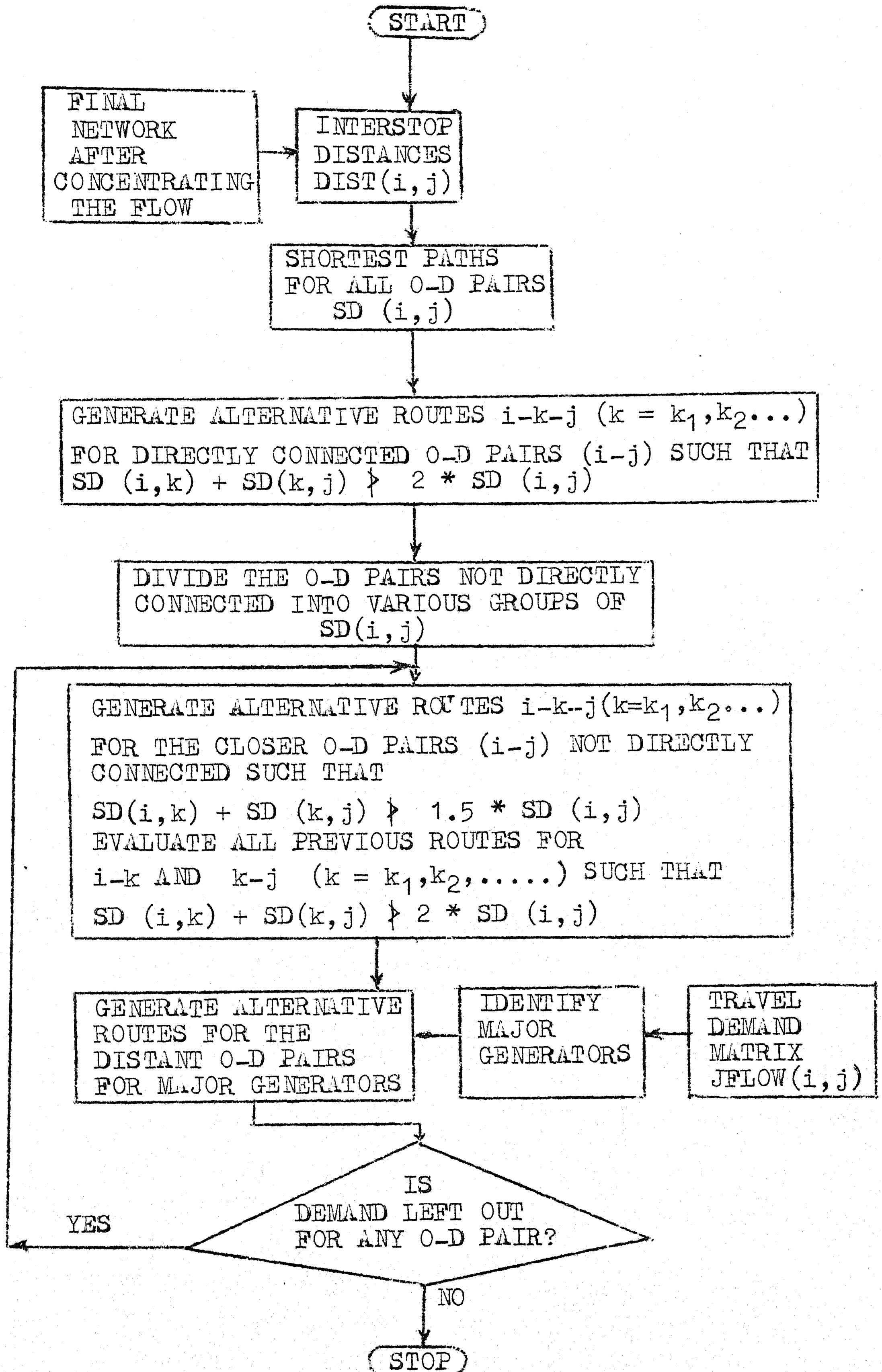


FIG. 2.4 : PROCEDURE FOR GENERATING POSSIBLE ROUTES

links l and k save the transfer at the intermediate node. When number of routes pass a node, there are a large number of turning flows at the nodes. It is proposed in this model to maximize the number of transfers saved. The various turning movements on a small network are shown in Fig. 2.5(b). Let $(TURNFL)_{lk}$ be the number of passengers per day going directly from link l to link k or vice versa. The estimated number of bus trips per day is $(NOBUS)_l$ on link l. If a route goes directly from link l to link k, the number of transfers saved per route trip for the route and this turning flow, is estimated by following relationship:

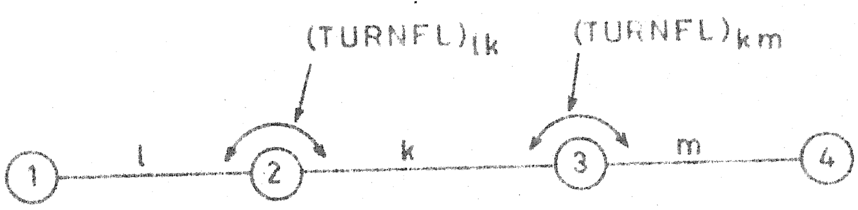
$$(NOTRAN)_{pr} = \frac{(TURNFL)_{lk}}{\text{Minimum}\left\{(NOBUS)_l,\ (NOBUS)_k\right\}} \qquad (2.10)$$

where

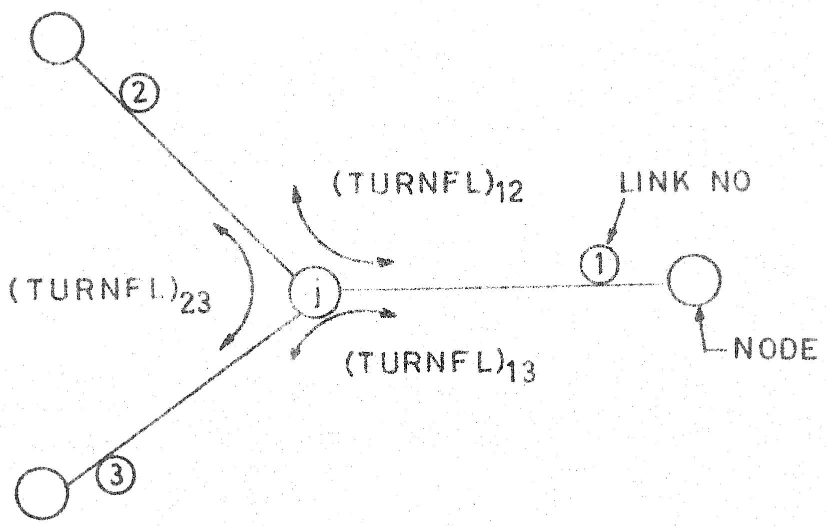
$(NOTRAN)_{pr}$ = Number of transfers saved for $p^{\underline{th}}$ turning flow of route r.

$\text{Minimum}\left\{(NOBUS)_l, (NOBUS)_k\right\}$ = The minimum value of the number of bus trips on the two links l and k.

The logic behind this relationship (Eqn. 2.10) is that no more than minimum $\left\{(NOBUS)_l, (NOBUS)_k\right\}$ buses can go directly from link l to link k, and that the turning



(a) TURNING MOVEMENTS ALONG A ROUTE



(b) TURNING MOVEMENTS AT A NODE j IN A PART OF A NETWORK

FIG. 2·5 NUMBER OF TRANSFERS SAVED ON A ROUTE.

passengers are evenly distributed on these links. This is normally a pessimistic estimate as other routes pass link l and k (but not both) as well and these should be subtracted.

The various steps for calculating the number of transfers saved on a sample route (Fig.2.5(a)) are as follows:

(i) Calculate the turning flow at a node i $(TURNFL)_{lk}$ where links l and k intersect by the following relationship:

$$(TURNFL)_{lk} = \sum_{t=i+1}^{NONODS} \sum_{s=1}^{i-1} JFLOW(s,t) \qquad (2.11)$$

where

JFLOW(s,t) = Flow of passengers between the O-D pair s-t.

NONODS = Number of nodes in a route.

(ii) Estimate the number of bus trips in each direction on the links of a route using the following relationship (Eqn. 2.5).

$$(NOBUS)_l = A\ ((LKFLOW)_l)^B$$

The link flow on link l i.e. $(LKFLOW)_l$ connecting the nodes i and j, is found out by the following relationship:

$$(LKFLOW)_l = \sum_{t=i+1}^{NONODS} \sum_{s=1}^{i} JFLOW(s,t) \qquad (2.12)$$

The value of JFLOW(s,t) is obtained from the O-D matrix.

(iii) The number of transfers saved at each node of a route is estimated by Eqn. 2.10.

(iv) The number of transfers saved is calculated for each turning flow along the route and added to the total for the route, to obtain the total number of transfers saved by a route, i.e. $(TTRAN)_r$. Fig. 2.6 shows the above procedure.

2.9 Model for Simultaneous Choice of Routes and Frequencies

The routing model estimates where the passengers are expected to travel in the optimal route system considering passenger riding time cost and operation cost. A large set of all possible routes which satisfy certain practical constraints is also generated. In this phase, optimal set of routes and their frequencies are obtained such that as many transfers as possible are avoided. The problem is formulated and solved as a linear programming problem(LP).

The objective function is

$$\text{Maximize } Z = \sum_{p=1}^{TTF} (NOTRN)_p \qquad (2.13)$$

where

TTF = Total number of turning flows in a networks.

$(NOTRN)_p$ = Number of transfers saved for the p^{th} turning flow.

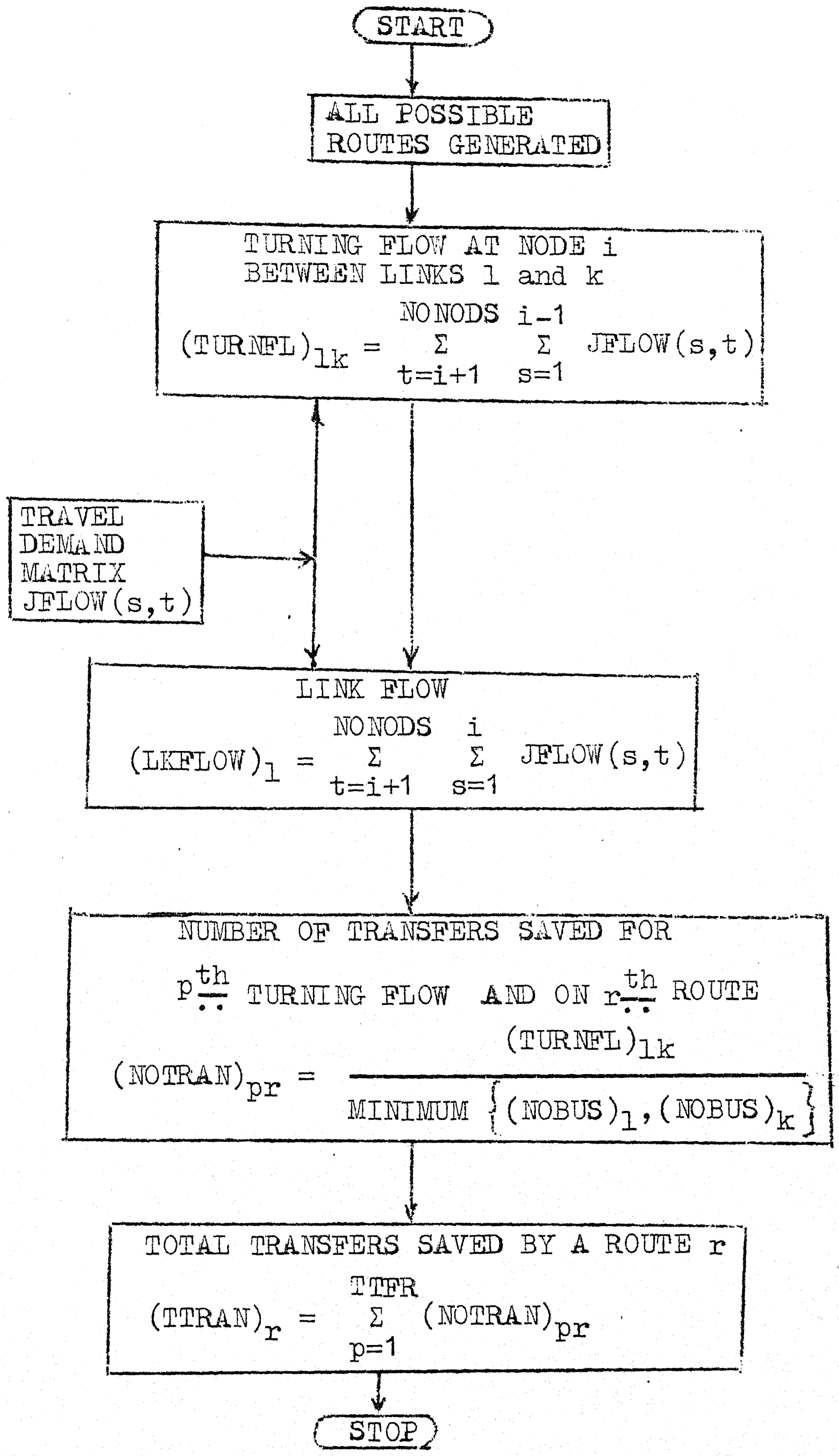


FIG. 2.6 : PROCEDURE FOR CALCULATING NUMBER OF TRANSFERS SAVED BY A ROUTE

$$(NOTRN)_p = \sum_{r=1}^{NR} (NOTRAN)_{pr} \ (FREQ)_r \qquad \forall p \qquad (2.14)$$

where

$(NOTRAN)_{pr}$ = Number of transfers saved for $p^{\underline{th}}$ turning flow of route r

NR = Number of routes in a network

$(FREQ)_r$ = Frequency on route r.

Substituting the value of $(NOTRN)_p$ the objective function (Eqn. 2.13) becomes:

$$Z = \sum_{r=1}^{NR} \sum_{p=1}^{TTFR} (NOTRAN)_{pr} \ (FREQ)_r \qquad (2.15)$$

$$Z = \sum_{r=1}^{NR} (TTRAN)_r \ (FREQ)_r \qquad (2.16)$$

where

$$(TTRAN)_r = \sum_{p=1}^{TTFR} (NOTRAN)_{pr} \qquad \forall r \qquad (2.17)$$

TTFR = Number of turning flows in a route.

The problem becomes

$$\text{Maximize} \quad Z = \sum_{r=1}^{NR} (TTRAN)_r \ (FREQ)_r \qquad (2.18)$$

Subject to following sets of constraints :

(i) $$\sum_{r=1}^{NR} (NOTRAN)_{pr} \cdot (FREQ)_r \leq (MAXTFL)_p \qquad \forall p \qquad (2.19)$$

(ii) $$\sum_{r=1}^{NR} (RTTIME)_r \cdot (FREQ)_r \leq (OT) \cdot (OPF) \qquad (2.20)$$

(iii) $0 \leq (FREQ)_r \leq (MAXFRE)_r \quad r$ (2.21)

(iv) $(NOTRN)_p \geq 0$ (2.22)

where OT = Operating time (hrs)

$(TTRAN)_r$ = Total number of transfers saved by a route r.

$(MAXTFL)_p$ = Maximum value of the turning flow for the p^{th} turning movement.

$(RTTIME)_r$ = Round trip time on route r.

$(MAXFRE)_r$ = Maximum frequency of route r.

OPF = Operating fleet size.

The constraint set (i) (Eqn. 2.19) contains TTF equations where TTF is the total number of turning flows in the network. The different values of the p^{th} turning movement are obtained for various routes. From these, the maximum value of the p^{th} turning movement is found out. So if turning flow p is of the size $(MAXTFL)_p$, no more than this number of transfers can be saved for this turning flow.

The constraint set (ii) (Eqn. 2.20) takes into consideration the operating fleet size. The operating fleet size is the actual number of buses operating on the road. The round trip time i.e. $(RTTIME)_r$ for a route is

found out by calculating the time to travel the total route length $(TRL)_r$ and adding the lay over time $(LOT)_r$. The round trip time on a route r is calculated by the following formula:

$$(RTTIME)_r = \frac{(TRL)_r}{AVERSP} + (LOT)_r \qquad (2.23)$$

where

AVERSP = Average speed of the bus (Kmph).

The average speed of the bus is estimated using the values of different speeds in different areas of the city. The lay over time at the destination of a route is estimated taking into consideration the route length. The sum of the product of the frequency and round trip time of all routes should not exceed the product of operating fleet size and operating time.

The constraint set (iii) (Eqn. 2.21) takes into consideration the upper bound on frequency for every route. The value of frequency which comes into the optimal solution should lie between one and maximum frequency.

The constraint set (iv) (Eqn. 2.22) takes into consideration the non-negativity requirements of the number of transfers saved for p^{th} turning flow.

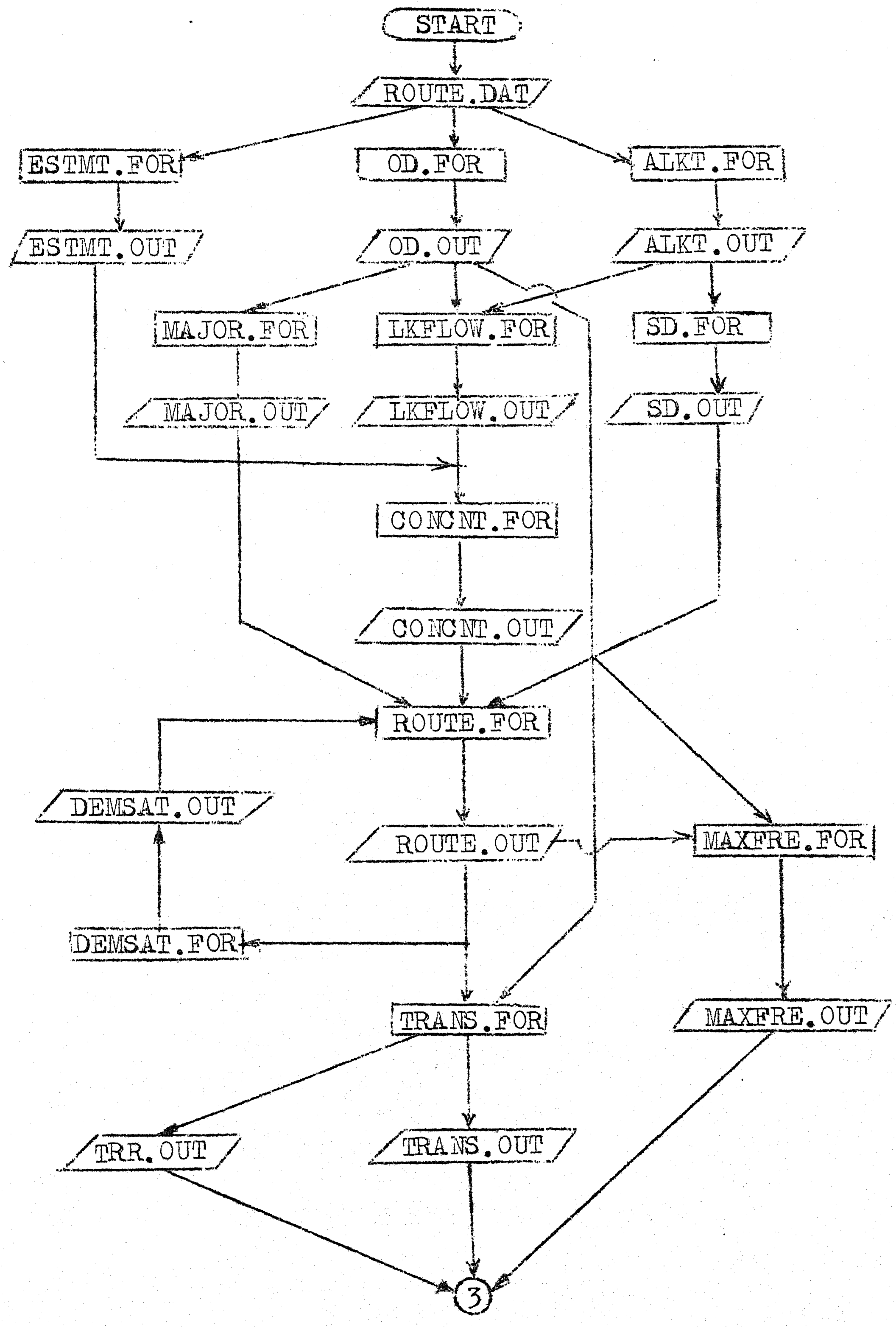
The model simultaneously gives the optimal set of routes and their frequencies for a given fleet size, so as to maximize the number of transfers saved. Experiment can be performed with different fleet sizes.

2.10 Development of Computer Programmes

The model for the simultaneous choice of routes and their frequencies and the various associated submodels has been discussed in the previous sections. The model is quite complex as it involves a lot of evaluation and data processing. A complete system of the computer programmes have been developed for the model. The system of programmes alongwith their interactions and working is shown in Fig. 2.7. The details of the system are as given below:

(i) To get the desire O - D matrix (OD.OUT), the computer programme OD. FOR is developed (Fig.2.1) . Input to this programme is ROUTE. DAT, which contains the data for all routes like number of stops on each route, number of passengers on each route and code number for the stops on the route.

(ii) To get the link table (ALKT.OUT) for the network, the programme ALKT.FOR is developed. Input to this programme is file ROUTE.DAT. Output from this programme is ALKT.OUT.


START
ROUTE.DAT
ESTMT.FOR
OD.FOR
ALKT.FOR
ESTMT.OUT
OD.OUT
ALKT.OUT
MAJOR.FOR
LKFLOW.FOR
SD.FOR
MAJOR.OUT
LKFLOW.OUT
SD.OUT
CONCNT.FOR
CONCNT.OUT
ROUTE.FOR
DEMSAT.OUT
ROUTE.OUT
MAXFRE.FOR
DEMSAT.FOR
TRANS.FOR
MAXFRE.OUT
TRR.OUT
TRANS.OUT
3

Contd....

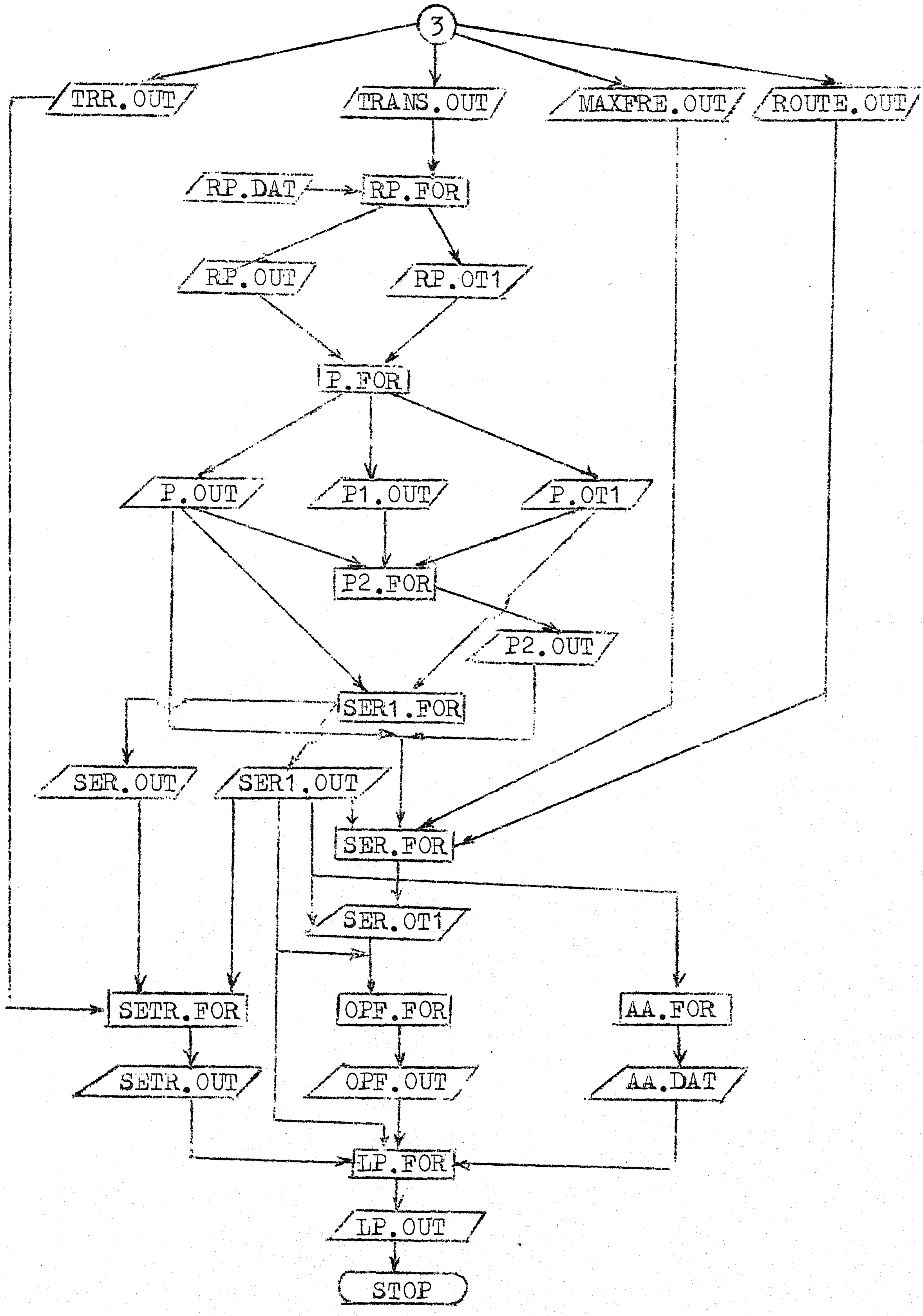


FIG.2.7 : DEVELOPMENT OF COMPUTER PROGRAMMES

(iii) To get the values of the coefficients W, A and B, for the concentration of flow a programme ESTMT.FOR is developed. As a result we get the relationship between the flow of passengers and the number of bus trips in unit time. Input to this programme ESTMT. FOR is ROUTE.DAT. Output file is ESTMT.OUT.

(iv) A programme LKFLOW.FOR is developed to get the link flow on each link using shortest path algorithm. Input to this programme is two files OD.OUT and ALKT.OUT . Output from this programme is LKFLOW.OUT.

(v) A programme SD.FOR is developed to get the shortest distance matrix for all O-D pairs using shortest path algorithm. Input to this programme is ALKT.OUT Output from this programme is SD.OUT.

(vi) A programme MAJOR.FOR is developed to scan the major O-D pairs from the file OD.OUT. Output from this programme is MAJOR.OUT which is used for the route generation.

(vii) A programme CONCNT.FOR is developed to evaluate the various networks of links and to get the final network with minimum total cost. Input files are LKFLOW.OUT and ESTMT.OUT. Output file is CONCNT.OUT.

(viii) A programme ROUTE.FOR is developed to generate the routes sequentially i.e. starting with those O-D pairs which are directly connected. Then the O-D pairs which are not directly connected are classified into various groups according to the shortest distance between them. Routes are first generated for the closer O-D pairs. By taking the output of closer O-D pairs as the input, routes for distant O-D pairs are generated. The input files are CONCNT.OUT, MAJOR.OUT and SD.OUT. Output from this file programme is ROUTE.OUT.

(ix) A programme DEMSAT.FOR is developed to check whether almost all demand is satisfied or not. Input file is ROUTE.OUT. Output file from this programme is DEMSAT.OUT. If the demand is not satisfied, some more routes are generated for that unsatisfied demand and this process is continued until almost all demand is satisfied.

(x) A programme TRANS.FOR is developed to calculate the number of transfers saved by each route. Input files for this programme are OD.OUT and ROUTE.OUT. Output files from this programme are TRR.OUT and TRANS.OUT. The file TRR.OUT gives the value of total transfers saved by each route. The file TRANS.OUT give all details of turning flow and

the number of transfers saved for each turning flow along each route.

(xi) A programme MAXFRE.FOR is developed to get the maximum value of frequency for every route. Input files are ROUTE.OUT and OD.OUT. Output from this programme is MAXFRE.OUT which gives the maximum frequency on each route.

(xii) For the LP solution, various programmes are developed to get the fixed parameters of the model namely constraint matrix, resources and objective coefficients. If the number of constraint equations is too large to accomodate in computer memory, the problem can be solved in parts. The various programmes are as follows:

(a) A programme RP.FOR is developed to scan those routes and turning flows from the file TRANS.OUT, which are of interest to the part of the network in question. The output files are RP.OUT and RP.OT1. The file RP.OUT contains details of designation of the p^{th} turning flow, its value and number of transfers saved for this turning flow. The file is RP.OT1 is used as the counter for the total number of all turning flows of all routes.

(b) A programme P.FOR is developed to rearrange the file RP.OUT i.e. rearranging all the turning movements on all the routes, so that the number of routes contributing for p^{th} turning movement can be identified. Input to this programme is RP.OUT and RP.OT1. The output files are P.OUT, P1.OUT and P.OT1. The file P.OUT is the arranged file which accumulates the p^{th} turning flow of different routes. This file gives the total number of turning flows. The file P1.OUT gives the value of the number of routes contributing to each p^{th} turning flow. The file P.OT1 is used as a counter for the total number of all turning flows on all routes.

(c) A programme P2.FOR is developed to get the maximum value of the p^{th} turning flow out of all the turning flows contributed by various routes. Input files are P.OUT, P1.OUT and P.OT1. The output file is P2.OUT.

(d) A programme SER1.FOR is developed to read the coefficient matrix (i.e. $(NOTRAN)_{pr}$ values). Input files are P.OUT, P.OT1. The output files are SER.OUT and SER1.OUT. The output file SER.OUT gives the values of p, r and $(NOTRAN)_{pr}$. The output file SER1.OUT gives the final value of number of routes in question.

(e) A programme SER.FOR is developed to get the maximum frequency and route-length for each route for the set of routes in question. Input files for this programme are MAXFRE.OUT, ROUTE.OUT, P.OT1, P.OUT, SER1.OUT. The output file is SER.OT1 which gives the route-length and maximum frequency for each route in question.

(f) A programme OPF.FOR is developed to get the value of operating fleet for the part of the network in question. The input files are SER1.OUT and SER.OT1. The output file is OPF.OUT which gives the value of operating fleet. The total operating fleet is divided for different parts of network according to the round trip-route time and the maximum frequency of the routes which contribute to the part of the network.

(g) A programme SETR. FOR is developed to get the value of the total number of transfers saved by each route in question. The input files are SER.OUT, TRR.OUT and SER1.OUT. The output file is SETR.OUT.

(h) A programme AA.FOR is developed to get the value of coefficients for constraint on the upper value of the frequency. Input files are SER1.OUT and P.OT1. The output file is AA.DAT.

After getting all the values of fixed parameters from the files SETR.OUT, SER1.OUT, OPF.OUT, SER.OT1, P2.OUT, AA.DAT and P.OT1, a programme LP.FOR is developed using IMSL subroutine Zx3LP and the solution containing the optimal number of routes and their frequencies is obtained.

3 APPLICATION OF THE MODEL

3.1 General

The model for generating an urban bus transit network with simultaneous choice of routes and frequencies through heuristic methods is described in the previous chapter. For the model to be of real use, it should be tested and validated using real world data. This model is applied in this study to the city of Ahmedabad for the design of the bus transit system. The following sections describe the application and the analysis of results.

3.2 Ahmedabad and its Bus Transit System

Ahmedabad is the sixth largest metropolis in India and in the western part of the country it ranks second in population next only to Bombay. Ahmedabad is the largest industrial city in the state of Gujarat with a population of 2.1 million which is likely to touch 3.6 million in 1991. It is the second fastest growing city ranking next only to Delhi. The municipal area is 24269 acres and the walled city area is 1361 acres . The population density of the city has risen from 11276 persons per square km (1941) to 17053 persons per square km in 1971 (WB, 1976).

The city of Ahmedabad is accessible by means of seven major highways and five major rail links of broad gauge and metre gauge from different parts of the state and the country. On account of high accessibility offered by the regional transport system i.e. road and rail, the city has physically grown in concentric shape. The city can be divided on area-wise basis into five zones namely Central, North, South, East and West. The Central zone i.e. walled city accounts for nearly 30 percent of the total population and has the highest density in the city. The North Zone has got textile industries. The South Zone has got industries related to iron and other small scale industries. The East Zone is commercial and residential. The West Zone has got educational and research institutions and is on the left bank of the river Subarmati. The most conspicuous feature of the land use system is the total inadequacy of the area devoted to roads and streets in Ahmedabad. In comparison with the cities of western world (London 23, Paris 25, Washington 30 percents) the 12.9 percent of the total area devoted to roads and streets in Ahmedabad is extremely low. The existing land use pattern for the city is shown in Fig. 3.1.

Bus transportation system in the city is operated by 'The Ahmedabad Municipal Transport Service' (A.M.T.S.),

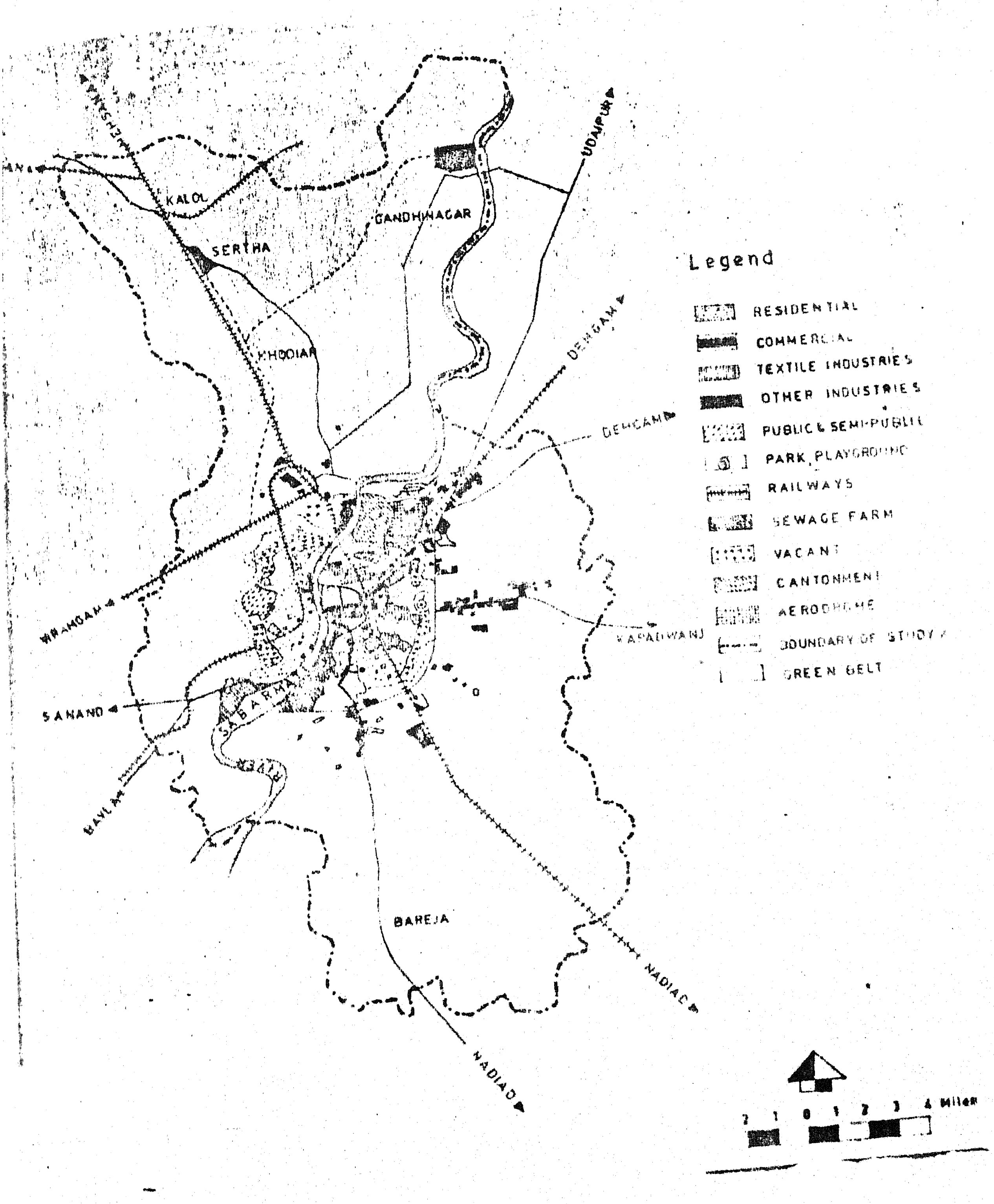


FIG. 3·1: EXISTING LAND USE FOR THE CITY OF AHMEDABAD.

which maintains a total operating fleet of 670 buses to cater to the needs of metropolis and the satellite townships. The A.M.T.S. has tried to keep pace with the rapid growth of Ahmedabad city and operates 191 bus routes, offering 10,600 scheduled trips, catering for approximate 8.5 lakh passengers per day (8.00 A.M. to 1.30 A.M.). There are 71 long distance services with route length of more than 12 kilometres. The average route length is 8.0 kilometres. The transit network consists of 745 stops covered by the A.M.T.S. The minor stops are not considered and their demands are transferred to the adjoining major nodes (with high passenger volume). The final network consists of 134 nodes (Fig. 3.2). The index for the various nodes shown in the Fig. 3.2 is given in Appendix I alongwith the number of existing routes touching these nodes.

The A.M.T.S. have been put to severe limitations on account of:

(i) Route expansion has largely been carried out on socio-political demands in the absence of a well-defined route location policy. Increase in the routes inconsistent with the fleet size have resulted in parallel operations, low load factors and low frequencies. As a result of this nearly one-third of the existing routes are uneconomical.

(ii) The present routing system lays heavy emphasis on the utilisation of Lal-Darwaja (Node 1) and Kalupur (Node 4) terminals. Nearly 174 of the existing 191 routes converge at either of these terminals. The facilities of these are already saturated and suffer from poor accessibility conditions.

(iii) The total annual passenger traffic has more or less remained static at 5.6 lakhs passengers per day between 1971 and 1976. Inconsistencies in passenger traffic trends coupled with increased usage of auto-rickshaws largely explain the deficiency in supply characteristics of public transport system.

(iv) The existing vehicle utilisation of 180 km/day is low in comparison to the prevailing norms for other cities (Table 3.1).

There is an urgent need for the rationalization of the existing transit route network for providing an efficient city bus service.

3.3 Data Requirements for the Model

Descriptive and quantitative information (data) about the particular system to be investigated by modelling is a prerequisite for the problem definition and problem formulation. The routes are to be constructed through

TABLE 3.1 : OPERATING CHARACTERISTICS OF BUSES IN AHMEDABAD AND OTHER CITIES (1978/1979)

Sl. No.	Characteristics	Bombay	Delhi	Ahmeda-bad	Vadro-dra	Lahore
1	Population (millions)	7.0	5.0	2.0	0.6	3.0
2	Buses for 100,000 population	24	46	24	23	12
3	Daily passengers carried per bus	2330	1150	1416	1170	612
4	Approximate average passenger trip-length (km)	5.5	9.9	4.14	3.0	7.5
5	Daily operated distance per bus (km)	219	220	180	138	141

the demand points in the city network. Therefore, data requirements for the routing model are:

(i) the demand points or nodes and prospective nodes in the urban street network;

(ii) the internodal distances and the corresponding riding times;

(iii) Origin-Destination Matrix;

(iv) operating Fleet-size.

3.4 Analysis of Field Data

3.4.1 Introduction

The accuracy of the system model depends upon the extent of availability of relaible data. Some data in raw form were available from the A.M.T.S. offices. To start with, the existing routes operated by A.M.T.S. are taken. The nodes touched by various routes and the route lengths are given in Table 3.2. The characteristics of all the 191 routes in terms of frequency (Number of trips in a day), trip travel time, number of buses operating, daily average traffic income, average load factor and the maximum fare for each of the route are given in Table 3.3. Table 3.2 indicates that the route lengths are between the range of 2.6 kms to 20 kms. The average route length is 8.00 kms. Table 3.3 indicates that the number of scheduled

TABLE 3.2 : PATHS OF EXISTING BUS ROUTES IN AHMEDABAD

ROUTE NO	ROUTE LENGTH	NODES TOUCHED BY THE ROUTE
1	5.40	1 13 7 8 9 4
2	4.20	4 10 5 11 12 1
3	4.25	1 12 11 5 10 4
4	4.90	4 9 7 13 1
5	8.40	4 9 8 7 26 27 28 29 31 32
6	5.55	32 33 6 5 10 4
7	8.75	4 10 5 6 33 32 81 137 88
8	9.10	88 79 82 89 90 93 26 7 8 9 4
9	9.33	4 9 8 7 26 93 90 89 82 79 88
10	8.75	88 137 81 32 33 6 5 10 4
11	7.05	4 9 8 7 26 99 100 84 101
12	7.05	4 9 8 7 26 99 100 105
13	7.10	4 9 8 7 26 99 100 84 85
14	6.90	1 30 8 7 26 99 110 111
15	7.75	1 30 8 7 26 99 110 111 142
16	6.85	1 66 95 94 26 99 110 111
17	12.30	17 39 34 19 6 11 12 1 30 8 7 26 99 110
18	5.50	1 66 95 94 26 99 100
19	6.70	4 9 8 7 26 99 110 111
20	10.90	110 99 26 7 8 9 4 10 57 103 51 61
21	5.45	4 9 8 7 26 99 100
22	9.15	1 66 95 94 26 99 110 120 125
23	9.20	1 30 8 7 26 99 110 120 125
24	19.75	17 40 39 34 41 5 11 12 1 30 8 7 26 99 110 120 121 123 122
25	12.50	1 66 95 94 26 99 110 120 121 123 124
26	10.50	1 30 8 114 76 120 121 123 122
27	11.95	4 9 8 7 26 99 110 120 121 122
28	9.25	4 9 8 7 26 99 110 120 121
29	11.95	4 9 8 7 26 99 110 120 121 123 124
30	11.95	4 9 8 7 26 99 110 120 121 124
31	6.80	4 9 8 114 76 120 125
32	9.70	4 9 8 114 76 120 121 123 124
33	9.75	4 9 8 114 76 120 121 122
34	3.40	110 120 125
35	13.20	124 123 121 120 110 99 102 27 90 82 79 88 137
36	3.40	110 120 125
37	14.00	68 67 32 95 94 26 99 110 120 121 122
38	14.70	123 121 120 110 99 26 7 8 114 76 58 45 62 74
39	9.50	123 121 120 59 58 45 62 74
40	16.11	122 132 121 120 110 99 26 7 8 114 76 58 45 62 63

CONTD......

TABLE 3.2 (CONTD.)

ROUTE NO	ROUTE LENGTH	NODES TOUCHED BY THE ROUTE												
41	4.50	15	14	8	25	1								
42	3.70	4	9	8	14	15								
43	5.50	16	15	14	7	8	77	4						
44	9.34	71	70	78	32	95	94	26	7	14	15			
45	10.10	1	30	8	114	76	59	46	47	48				
46	7.50	1	30	8	114	76	59	47						
47	5.15	1	30	8	114	76	59	46						
48	5.15	1	30	8	114	76	59	46						
49	10.20	4	42	43	58	76	59	46	47	48				
50	10.16	59	76	114	8	77	4	24	23	107	21			
51	7.80	1	30	9	42	58	45	56	55					
52	5.50	1	30	9	42	56	55							
53	8.65	1	30	9	42	58	45	62	63					
54	7.20	11	5	10	4	42	58	45						
55	6.55	4	42	58	45	62	63							
56	10.40	63	62	55	56	42	4	10	57	20	53	130		
57	11.14	140	33	12	11	5	10	4	42	43	45	62	55	
58	6.40	11	5	10	4	42	56	45						
59	3.35	4	42	56	55									
60	10.15	88	79	82	90	93	26	7	8	9	42	56	55	
61	8.45	1	25	77	4	54	138	117						
62	10.40	1	12	11	5	10	4	54	138	117	118			
63	11.00	10	4	54	138	117	48							
64	4.05	10	4	54	138									
65	6.55	10	4	54	138	117								
66	7.00	10	4	54	138	117	118							
67	15.80	117	138	54	4	9	8	114	76	120	121	123	132	
68	9.45	1	13	7	8	9	4	24	22					
69	7.35	22	53	57	10	5	11	12	1					
70	7.75	1	12	11	5	10	57	53	22					
71	9.45	22	24	4	9	9	7	13	1					
72	7.80	1	25	77	4	24	96	108						
73	6.75	4	21	112	113	119								
74	6.75	4	21	23	107	119								
75	5.67	4	24	95	53									
76	4.25	4	10	57	52	97	53							
77	5.65	53	96	24	4									
78	12.80	22	96	24	4	9	8	7	26	93	90	82	79	88
79	11.15	24	4	9	8	7	26	99	102	89	82			
80	10.35	1	12	11	5	57	52	53	130	133				

CONTD........

TABLE 3.2 (CONTD.)

ROUTE NO	ROUTE LENGTH	NODES TOUCHED BY THE ROUTE											
81	14.30	82	90	93	86	66	1	12	11	5	57	52	53
82	6.85	1	25	77	4	10	57	52	53				
83	10.30	1	12	11	5	57	52	53	130	134			
84	5.65	10	57	20	53	130	134						
85	5.10	4	10	57	20	53	22	108					
86	5.30	10	57	52	109	135							
87	7.20	52	57	10	4	42	43	45	62				
88	2.85	10	57	52	109								
89	15.22	82	81	32	33	6	19	34	50	60	136	61	135
90	6.65	1	12	11	5	41	50	60	136				
91	8.00	1	12	11	41	5	50	60	49				
92	6.95	1	12	11	6	106	50	60					
93	9.55	1	80	5	19	34	39	40	17	49			
94	9.10	1	12	33	41	106	40	60	49				
95	11.85	136	60	50	41	5	10	4	42	56	62	63	
96	11.35	49	60	50	41	5	10	4	42	56	62	63	
97	7.30	1	12	11	6	19	64	139					
98	8.40	1	12	11	6	19	34	18	35	36			
99	7.80	10	3	5	6	19	18	35	36				
100	4.75	1	12	33	140								
101	6.40	1	12	33	65	64	139						
102	6.40	1	12	33	64	139							
103	6.40	1	12	33	64	139							
104	6.50	10	5	6	19	64	139						
105	7.85	1	66	95	75	32	67	68	69				
106	7.85	1	66	95	75	32	67	68	69				
107	7.65	1	66	95	75	32	31	73	72	141			
108	10.00	10	5	11	12	33	32	67	68	69			
109	10.00	10	5	11	12	33	32	67	68	69			
110	6.70	1	66	86	87	137	91	92					
111	6.75	1	66	86	93	90	104						
112	12.20	1	30	8	7	26	99	110	120	121	122		
113	12.10	1	66	95	94	26	99	110	120	121	122		
114	10.00	1	30	8	114	76	120	121	122				
115	11.95	4	9	8	7	26	99	110	120	121	122		
116	6.45	110	120	121	124								
117	11.35	17	40	34	41	5	10	4	51	138	117		
118	6.50	10	4	54	138	117							
119	6.50	10	4	54	138	117							
120	6.10	4	24	112	113	119							

CONTD........

TABLE 3.2 (CONTD.)

ROUTE NO	ROUTE LENGTH	NODES TOUCHED BY THE ROUTE															
121	8.05	1	12	11	5	57	103	51	135								
122	3.55	10	57	20	53	130											
123	3.55	10	57	20	53	130											
124	6.60	1	12	11	5	41	50	60	136								
125	6.60	1	12	11	5	41	50	60	136								
126	6.60	1	12	11	5	41	50	60	136								
127	2.60	1	2	3	4												
128	3.55	1	2	3	5	6											
129	11.50	21	107	23	24	4	77	25	13	7	14	15					
130	8.80	1	12	11	6	19	34	18	35	36							
131	7.00	38	17	39	34	41	5	3	4								
132	6.10	17	39	40	41	5	3	4									
133	13.80	17	39	40	50	51	52	109	53	23	24	112	55	56	45		
134	15.70	17	39	40	50	57	20	53	23	24	112	55	56	45	58	76	59
135	15.50	17	60	61	51	53	108	107	23	24	112	55	56	62	63		
136	7.50	4	3	5	65	64											
137	4.27	1	13	14	15	16											
138	12.10	17	18	19	6	5	10	4	9	7	14	15					
139	7.50	39	17	39	40	41	5	10	4								
140	16.95	38	17	39	40	41	5	10	4	42	43	44	46	47	48		
141	9.00	49	18	34	19	6	5	10	4								
142	4.15	10	5	6	65												
143	8.85	1	66	75	32	67	68	69									
144	12.15	17	39	34	41	5	11	12	1	66	75	32	67	68			
145	5.50	1	66	75	32	78	70	71									
146	13.60	72	73	31	32	75	66	1	30	9	42	43	45	62	74		
147	4.25	1	66	75	32	67											
148	15.20	32	75	66	13	7	14	15	16	75	59	58	45	62	63		
149	11.20	4	77	25	1	66	75	32	31	73	72	141					
150	4.85	1	66	75	32	78	70										
151	14.80	69	67	32	75	66	1	12	11	5	10	4	24	23	107	21	
152	4.70	4	24	23	107	21											
153	8.40	4	10	5	11	12	33	78	70	71							
154	8.10	69	67	32	33	6	5	10	4								
155	14.30	69	67	32	75	95	65	1	25	77	4	42	43	45	62	63	
156	5.80	1	25	77	4	42	43	44									
157	9.55	4	3	2	12	33	32	31	73	72							
158	6.50	4	3	2	12	33	32										
159	8.05	4	3	2	80	78	70	71									
160	10.15	69	67	32	81	29	82	83	84	85							

CONTD........

TABLE 3.2 (CONTD.)

ROUTE NO	ROUTE LENGTH	NODES TOUCHED BY THE ROUTE														
161	12.65	17	40	39	34	19	33	32	31	73	88	79	82			
162	4.05	1	66	86	81	137										
163	12.35	38	17	39	34	41	5	11	12	1	66	86	87	137	88	
164	4.95	1	66	86	81	137	88									
165	3.30	1	66	86	81											
166	8.40	4	77	25	1	66	86	87	137	91						
167	13.05	88	79	82	90	93	26	7	8	114	76	58	45	62	63	
168	12.60	88	79	82	89	90	93	26	7	8	114	76	59	47		
169	13.50	38	18	19	6	11	12	1	65	86	87	28	82			
170	13.50	17	18	19	6	11	12	1	66	86	87	28	82			
171	12.80	17	39	34	19	6	11	12	1	66	86	87	28	82		
172	13.50	17	40	34	19	6	11	12	1	66	86	87	28	82		
173	7.18	1	66	95	94	93	90	89	82	79						
174	7.75	82	28	86	66	1	12	33								
175	6.10	1	66	86	93	90	82									
176	9.85	4	77	25	1	66	86	93	90	89	82					
177	10.56	4	3	2	1	56	86	93	90	89	82	98				
178	12.50	17	39	34	41	5	11	12	1	65	85	93	90	82		
179	14.25	17	18	19	6	11	12	1	30	8	7	26	99	100	84	101
180	7.90	1	66	85	28	27	84	101								
181	7.90	1	66	86	28	27	84	85								
182	5.90	1	30	8	7	26	27	102								
183	7.65	1	30	8	7	26	27	83	104							
184	5.85	1	66	95	94	93	27	102								
185	7.30	1	30	8	7	26	99	100	84	85						
186	7.30	1	30	8	7	26	99	100	105							
187	7.20	1	66	95	94	26	99	102	84	85						
188	7.15	1	66	95	94	26	99	102	105							
189	5.70	4	9	8	7	26	27	102								
190	7.50	4	9	8	7	26	27	83	104							
191	3.60	53	52	57	10	4										

TABLE 3.3 : DETAILS OF EXISTING BUS ROUTES IN AHMEDABAD

ROUTE NO.	NO. OF TRIPS	TRIP TIME	NO. OF BUSES	DAILY AVERAGE INCOME	AVERAGE LOAD FACTOR %	MAXM FARE
1	20	25	1	336	47	25
2	30	20	1	336	47	25
3	26	20	1	250	40	25
4	26	21	1	250	40	25
5	15	36	1	239	34	30
6	15	24	1	239	34	30
7	40	15	4	1439	63	35
8	40	15	4	1439	63	35
9	40	20	4	1382	63	35
10	40	22	4	1382	63	35
11	41	30	3	1234	57	50
12	47	30	2	780	56	50
13	81	30	3	1491	60	50
14	115	32	4	1492	60	45
15	47	26	2	974	54	60
16	15	25	1	175	43	45
17	135	55	7	3641	53	60
18	30	21	1	394	49	45
19	48	30	4	1499	70	45
20	120	50	7	4547	63	55
21	20	25	1	240	36	35
22	78	36	3	1514	53	55
23	37	32	2	673	51	55
24	28	80	2	802	51	70
25	66	45	3	1353	51	60
26	21	35	1	402	46	55
27	41	50	2	920	54	50
28	22	39	1	360	41	60
29	82	45	4	1765	51	60
30	22	45	1	433	44	60
31	30	21	1	486	55	55
32	56	30	2	1016	55	55
33	22	30	1	361	46	55
34	14	9	1	271	38	40
35	20	50	1	226	34	60
36	18	14	1	271	38	45
37	52	50	2	732	46	60
38	19	50	1	476	48	65
39	20	35	1	354	38	55
40	14	55	1	408	45	70
41	72	20	3	726	56	30
42	102	20	3	832	50	30
43	30	25	1	216	39	30
44	35	25	1	244	30	50
45	60	30	3	1158	48	55
46	107	22	4	1240	45	55
47	14	20	1	100	34	55
48	22	20	1	277	38	50
49	58	40	3	1042	45	55
50	15	42	1	69	30	35

contd......

TABLE 3.3 (contd.)

ROUTE NO.	NO. OF TRIPS	TRIP TIME	NO. OF BUSES	DAILY AVERAGE INCOME	AVERAGE LOAD FACTOR %	MAXM FARE
51	60	35	2	589	54	45
52	96	21	3	342	50	45
53	126	35	5	1723	56	50
54	98	35	2	411	48	25
55	[illegible]	30	1	283	49	40
56	12	50	1	78	31	50
57	[illegible]	60	7	3373	65	60
58	[illegible]	25	1	221	36	30
59	72	15	2	140	44	35
60	[illegible]	40	1	90	35	55
61	[illegible]	30	10	3522	53	60
62	[illegible]	35	1	163	32	55
63	[illegible]	35	6	3242	64	60
64	12	20	1	390	59	35
65	98	20	3	1329	54	50
66	125	20	4	1860	56	45
67	12	60	1	254	34	70
68	10	25	1	330	50	30
69	10	20	1	330	50	30
70	10	16	1	270	41	30
71	10	20	1	270	41	30
72	141	30	9	3468	62	50
73	141	20	4	1498	48	45
74	63	20	2	877	58	40
75	20	15	1	160	24	25
76	20	12	1	214	35	25
77	20	15	1	214	35	25
78	10	48	1	111	42	60
79	9	50	1	123	30	60
80	93	40	5	1102	46	50
81	9	45	1	98	42	60
82	24	25	1	245	36	45
83	12	50	1	354	52	55
84	36	20	1	414	57	30
85	119	17	3	1240	58	40
86	37	26	1	416	60	40
87	53	25	1	142	30	20
88	38	14	1	504	77	35
89	23	55	1	171	31	70
90	115	25	4	1726	54	45
91	40	30	2	678	44	50
92	20	25	1	78	28	50
93	21	35	1	266	36	45
94	20	35	1	250	35	50
95	36	55	2	961	63	60
96	36	55	2	961	61	60
97	57	25	4	2225	59	60
98	24	27	1	500	51	60
99	20	32	1	411	56	60
100	21	21	1	264	38	55

contd.....

TABLE 3.3 (contd.)

ROUTE NO.	NO. OF TRIPS	TRIP TIME	NO. OF BUSES	DAILY AVERAGE INCOME	AVERAGE LOAD FACTOR %	MAXM FARE
101	[illegible]	25	1	454	48	50
102	19	25	3	944	42	60
103	27	25	1	415	53	60
104	40	22	2	878	48	60
105	[illegible]	25	5	2163	59	60
106	21	25	1	455	52	60
107	17	30	2	927	59	55
108	[illegible]	42	3	1383	57	60
109	[illegible]	42	2	891	55	60
110	47	21	2	1014	62	50
111	65	17	3	1432	52	60
112	15	55	1	338	44	60
113	36	50	2	798	43	65
114	[illegible]	35	1	334	41	55
115	18	50	1	354	46	65
116	26	15	1	419	37	50
117	174	41	9	6650	62	60
118	40	22	2	958	60	55
119	60	20	3	1918	62	60
120	24	24	1	355	44	50
121	34	30	2	666	49	60
122	187	12	7	4636	66	60
123	84	12	3	1719	69	60
124	31	17	3	881	47	70
125	35	17	3	803	45	65
126	27	23	2	647	46	65
127	263	15	5	1983	69	25
128	167	20	3	804	55	30
129	47	65	2	484	43	35
130	71	35	3	1266	55	50
131	93	26	3	922	54	40
132	60	25	2	576	48	40
133	41	40	3	1054	60	60
134	52	50	3	1119	48	60
135	47	55	4	1576	59	65
136	56	35	2	533	38	40
137	56	24	1	151	29	35
138	20	45	1	78	38	25
139	28	28	1	248	37	45
140	27	65	2	616	39	65
141	25	36	1	228	35	45
142	40	16	1	234	37	30
143	31	39	1	343	50	60
144	102	50	6	3465	59	60
145	95	25	3	1377	60	45
146	117	50	7	3011	63	60
147	32	16	1	351	51	40
148	40	60	2	679	45	60
149	91	32	4	1352	54	55
150	36	20	1	333	40	30

contd...

TABLE 3.3 (contd.)

ROUTE NO.	NO. OF TRIPS	TRIP TIME	NO. OF BUSES	DAILY AVERAGE INCOME	AVERAGE LOAD FACTOR %	MAXM FARE
151	42	60	3	1222	57	65
152	106	20	4	1309	70	65
153	23	30	1	341	48	50
154	50	30	2	644	45	50
155	80	65	3	985	51	65
156	23	24	1	215	32	50
157	44	41	2	626	46	50
158	60	24	3	634	55	50
159	50	35	2	940	65	50
160	48	30	2	845	53	55
161	24	50	1	362	47	50
162	35	14	1	294	39	40
163	64	50	4	1524	54	60
164	28	15	1	239	37	40
165	31	13	1	250	35	40
166	131	45	6	2030	59	50
167	30	45	2	495	51	60
168	19	45	1	219	32	60
169	28	50	2	465	47	60
170	16	50	1	346	46	60
171	54	50	3	999	47	60
172	64	50	4	1208	43	60
173	24	23	1	324	46	50
174	22	28	1	158	27	50
175	32	20	1	225	43	40
176	70	45	4	1178	61	50
177	78	53	4	1257	54	55
178	68	50	4	1477	53	60
179	139	35	7	3570	55	65
180	32	25	1	265	32	50
181	32	25	1	265	32	50
182	30	20	1	272	38	40
183	40	30	2	548	49	50
184	34	20	1	333	42	40
185	60	30	2	923	55	50
186	53	30	2	1009	64	50
187	54	26	2	753	60	50
188	29	30	1	406	56	40
189	62	30	2	511	40	40
190	26	25	1	317	48	45
191	20	12	1	160	24	25

trips in a day for various routes are in the range of 9 to 263. Generally the number of trips is less for longer routes and is more for shorter routes in central business district and other high density areas. The trip travel time for various routes is in the range of 15 minutes to 65 minutes and in the walled city area (C.B.D. area) the travel time is higher for the same distance than other areas due to the low speeds (5 kmph).

The number of buses operating an each route in a day is in the range of 1 to 10. This number depends on the frequency and round trip time for a route. The daily average traffic income on each route is in the range of Rs. 4636 to Rs. 69.

By studying the load factors for various routes, routes can be classified on load factor criterion (Table 3.4). The load factor is an important indicator for measuring the efficiency of the existing route pattern. The expenditure and revenue break even at 62 percent whereas operating cost and revenue break even at 45 percent. The low value of break even load factor is largely due to a well balanced fare structure.

Table 3.4 indicates that nearly 35 percent of the existing routes operate below the economical value.

TABLE 3.4 : CLASSIFICATION OF ROUTES BY LOAD FACTORS

Sl.No.	Load Factor Percentage	Number of Routes	Percent
1	Less than 45	66	35
2	45 to 62	107	56
3	62 and above	18	9
	Total	191	100

3.4.2 Trip Distribution

The model developed in this study needs the volume of the distribution of trips between various nodes. The A.M.T.S. has not collected origin-destination survey to obtain the trip distribution. The desired O - D matrix is generated, based on the available information of routes, in following steps:

(i) Average link volume on each route during the day is obtained from load factor and maximum fare criteria.

(ii) Each stop on a route is assigned a weight depending upon the importance of the stop quantitatively measured in terms of number of routes touching the stop. These weights are used to define the probability of trip generation on each stop of the route.

(iii) The generated trips at a stop are then distributed to other stops of the route using the relative weights of the different stops.

(iv) The trip distribution matrix for the network is obtained by combining the distribution of all the routes.

The various steps of this procedure are explained in the following sub-sections.

Average Link Volume on Each Route: The daily volume of passengers served by each route is not available from the A.M.T.S. records. However, daily income of a route, fare between the different stops and load factor of the route are obtained. The expected average link volume on each route is first obtained using the load factor and maximum fare criteria:

(a) Load Factor Criterion: The daily average link volume on each route is obtained by the following relation:

$$(VOLP1)_i = (TRIPS)_i * (LF)_i * (CAP) \qquad (3.1)$$

where

$(VOLP1)_i$ = Average link volume on route i by load factor criterion.

$(TRIPS)_i$ = Number of scheduled bus trips in a day for route i.

$(LF)_i$ = Average link load factor for route i.

(CAP) = Maximum number of passengers that can be accomodated in a bus (60).

(b) Maximum Fare Criterion: The daily average link volume on each route is obtained by the following relation:

$$(VOLP2)_i = \frac{(INCOME)_i}{(MAXF)_i} \qquad (3.2)$$

where

$(VOLP2)_i$ = Average link volume on route i by maximum fare criterion.

$(INCOME)_i$ = Daily average traffic income in paise for a route i.

$(MAXF)_i$ = Maximum fare in paise for a route i.

The load factor criterion is a good estimate for the link flow provided the load factor for each link is used. The average link load factor as obtained from the records is not a very good estimate in situation where there are large variation in load factors of the various links. The average link volume is then also calculated

using the income from the route and the maximum fare on the route. The link volume obtained from these two different criterion are quite close in heavily travelled routes. The maximum fare criterion gives higher link volume in case of longer routes where as load factor criterion gives higher link volume for shorter routes. Due to the variations in the link volume obtained by these two criteria, the maximum of the two is taken for further analysis. The average flow on a link for each direction of a route is taken to be half of the total link flow.

Trip Generation at Various Stops of the Route: The volume of passengers on a link for a particular direction are destined for one of the remaining stops of the route. The major stops attract more passengers than the minor stops. It is desirable that to distribute the trips to various stops, some weightage be assigned to them. The importance of a stop can be judged in terms of the routes passing through it. The number of such interested routes for each stop of a route in a particular direction are determined. Using the number of interested routes for each stop, the probabilities of getting down at different stops are estimated. Let NR1, NR2,.... NR_n be the number of interested routes touching the stops 1,2,3,..., NONODS for a particular direction of a route.

The flow on a link (i-j) i.e. $(FLOW)_{i-j}$ is distributed among the remaining stops of the route i.e. j, j+1, ..., NONODS. The probability of a passenger to get down at any of these stops is given by

$$(Prob)_k = \frac{(NR)_k}{\sum_{k=j}^{NONODS} NR_k} \tag{3.3}$$

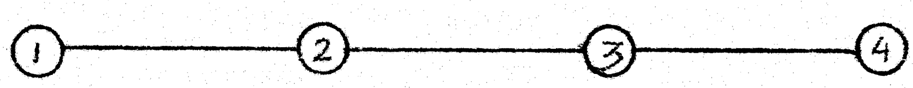
where

$(Prob)_k$ = Probability of a passenger to get down at the stop k of a route.

NR_k = The number of interested routes touching the stop k of a route.

NONODS = Number of stops in a route.

The number of passengers destined for various stops of the route are thus estimated using the above probabilities. It is assumed that the volume of passengers produced at the stop is same as that attracted to it. A sample calculation for one route is given below:



The nodes touched by a route are 1-2-3-4. The number of interested routes for each of this node (stop) are 57, 6, 10 and 31. The link flow of passengers in one direction is 5444. The trip generation at various stops 2, 3 and 4 for direction (1-4) is obtained in the following way:

$$(\text{Prob})_2 = \frac{6}{6 + 10 + 31} = \frac{6}{47}$$

$$(\text{Prob})_3 = \frac{10}{6 + 10 + 31} = \frac{10}{47}$$

$$(\text{Prob})_4 = \frac{31}{6 + 10 + 31} = \frac{31}{47}$$

Let $(\text{TRIPSG})_i$ be the number of trips generated at the stop i. The flow on a link (1,2) (i.e. 5444) is distributed among the remaining stops 2, 3 and 4.

$$(\text{TRIPSG})_2 = (5444) * \frac{6}{47} = 695$$

$$(\text{TRIPSG})_3 = (5444) * \frac{10}{47} = 1158$$

$$(\text{TRIPSG})_4 = (5444) * \frac{31}{47} = 3591$$

The trips generated at the stop 2 i.e. 695 is distributed among the remaining stop 3 and 4 in the similar way. The total trips (column total) generated at the stop 3 has to

to to stop 4. In this way the upper trrange of the trip matrix is derived. The bottom triangle is derived similarly by considering the other direction (4-1).

The result of the above calculations in a form of a matrix are given in Table 3.5.

TABLE 3.5 : TRIP DISTRIBUTION MATRIX FOR A ROUTE

O \ D	1	2	3	4
1	-	695	1158	3591
2	518	-	170	525
3	674	71	-	1328
4	4252	447	745	-

Origin-Destination Matrix: The trip distribution matrices of all the 191 routes are combined to find the O-D matrix for the entire network.

The traffic flow volume data used in the analysis is for the year 1979 and it needs to be updated for the year ,1982. The A.M.T.S. records shows that the annual average growth of passenger traffic is 12.6 percent.

Using this uniform growth the O-D matrix for the city is updated for 1982 and is given in Appendix II. The two most important major generators are Lal-darwaja and Kalupur which generates 1, 08, 371 and 1, 12, 102 trips respectively.

3.4.3 Riding Time on Links

For the concentration of link flows on the network, the riding times on various links need to be estimated. The riding time on a link depends upon the characteristics of the link like width, traffic volume its composition, and various traffic control measures on the link. Riding times are not available from the A.M.T.S. records but the travel time of the bus on a route is available. The total riding time of a route r i.e. $(TRT)_r$ is estimated using the following relationship:

$$(TRT)_r = (TT)_r - (TST)_r \tag{3.4}$$

$$(TST)_r = \sum_{j=1}^{NONODS-1} (ST)_j \tag{3.5}$$

where

$(TRT)_r$ = Total riding time on route r.

$(TT)_r$ = Total travel time in one direction for route r.

$(TST)_r$ = Total service time in one direction for route r.

$(ST)_j$ = Service time (dwelling time) at the j^{th} stop of the route.

The service time of passengers at a stop for a bus comprises of boarding time, alighting time and booking time. At most of the stops, it has been observed that the buses are allowed to depart before the tickets are issued. Hence, it is not necessary to include the booking time in reckoning with service times. It has also been observed that there are two doors with boarding and alighting operations taking place simultaneously. Based on the observations of service times made in Kanpur at different stops, Dhingra (1980) has established the following relationship for the service times:

$$y = 6.911 + (2.2525)X \text{ for } X > 0 \qquad (3.6)$$

where

y = Alighting time in secs.

X = Number of passengers alighting.

The total service time $(TST)_r$ along the route is estimated as follows using Dhingra's relationship (Eqn.3.6).

$$(TST)_r = 6.911\ (NONODS-1) + 2.25\ \left(\frac{(NUMP)_r}{(BUSTRP)_r} \right) \qquad (3.7)$$

where

$(NUMP)_r$ = Number of passengers served by a bus trip of a route r in one direction.

$(BUSTRP)_r$ = Number of bus trips for a route r.

After estimating the total service time for a route r in one direction, the total riding time $(TRT)_r$ is calculated by Eqn. 3.4. The riding time on link i traversed by route r is calculated by the following equation:

$$(RT)_{ir} = (TRT)_r * \frac{(LNGTH)_i}{\sum_{i=1}^{NLINKS} (LNGTH)_i} \qquad (3.8)$$

where

$(RT)_{ir}$ = Riding time on link i traversed by route r.

$(LNGTH)_i$ = Length of link i.

NLINKS = Number of links in a route.

It is observed that there is some variation in riding time obtained for links served by the number of routes. The average value of the riding time is used for further analysis.

3.5 Preparation of Road Network

The routing model discussed in Chapter 2, concentrates the flow on the links. To start with, a network, consisting of links where it is possible for buses to travel, is needed. The existing route network has 492 links (i.e. 246 links in each direction). To this 22 more links are added on which it is possible for the buses to travel.

The resulting network consists of 514 links. The characteristics of various links of the above network like nodes at ends, length, riding time are obtained and given in Table 3.6.

3.6 Concentrating Passenger Flows

3.6.1 General

The routing model estimates where the passengers are expected to travel in the optimal route system. If all the passengers travel along their shortest paths, this would imply a very dispersed route network with low vehicle utilization and many vehicle hours. On the other hand if the vehicles are filled to capacity, this would imply that passengers are concentrated to large flows and thus have to make substantial detours from their shortest paths, with increased riding time for the passengers. To get a reasonable compromise between these two extremes the sum of operation cost and passenger-riding-time cost can be minimized for a fixed desired O-D matrix.

Let RT_i be the riding time on link i and $((LKFLOW)_i)$ is the passenger flow in unit time on link i then the total riding time for all the passengers is $\sum_i (RT_i)((LKFLOW)_i)$ and the total vehicle time for the network is $\sum_i (RT_i)(NOBUS)_i$ where $(NOBUS)_i$ is the number of bus trips to be made in a

TABLE : 2.5 CHARACTERISITCS OF BUS TRANSIT NETWORK

LINK NO.	NODES AT ENDS		RIDING TIME
1	1	2	5.25
2	1	12	3.54
3	1	13	4.71
4	1	25	3.74
5	1	30	2.90
6	1	66	5.65
7	1	80	3.14
8	2	3	3.52
9	2	5	5.70
10	2	12	7.50
11	2	80	3.47
12	3	4	3.95
13	3	5	4.23
14	3	10	2.30
15	4	9	4.46
16	4	10	3.01
17	4	24	7.57
18	4	42	5.06
19	4	54	6.70
20	4	77	3.74
21	5	6	2.00
22	5	10	3.68
23	5	11	2.92
24	5	41	3.56
25	5	50	8.91
26	5	57	5.12
27	5	65	16.65
28	6	11	2.85
29	6	19	5.59
30	6	33	4.13
31	6	65	9.29
32	6	80	6.97
33	6	106	6.68
34	7	8	2.73
35	7	9	5.72
36	7	13	4.50
37	7	14	4.34
38	7	26	4.19
39	8	9	2.51
40	8	14	5.26
41	8	25	6.51
42	8	30	4.84
43	8	77	7.81
44	8	114	1.93
45	9	30	6.01
46	9	42	3.85
47	10	57	2.50
48	11	12	2.15
49	11	41	2.97
50	12	33	2.90
51	13	14	10.99
52	13	25	5.47

contd.....

TABLE 3.6 (contd.)

LINK NO.	NODES AT	ENDS	RIDING TIME
53	13	66	4.16
54	14	15	2.84
55	15	16	1.30
56	15	110	5.70
57	16	76	5.22
58	17	18	4.73
59	17	38	3.26
60	17	39	3.13
61	17	40	2.71
62	17	49	5.45
63	17	60	6.06
64	18	19	7.64
65	18	34	5.88
66	18	35	2.16
67	18	38	1.59
68	18	40	6.50
69	19	33	5.28
70	19	34	3.77
71	19	64	5.88
72	20	53	2.53
73	20	57	3.21
74	21	107	2.28
75	21	108	6.40
76	22	24	4.55
77	22	53	2.79
78	22	96	2.50
79	22	108	1.18
80	23	24	3.57
81	23	53	4.99
82	23	107	4.64
83	24	96	5.05
84	24	112	2.50
85	25	77	3.95
86	26	27	2.27
87	26	93	3.44
88	26	94	4.61
89	26	99	3.12
90	27	28	4.27
91	27	83	6.93
92	27	84	5.67
93	27	90	3.63
94	27	93	3.14
95	27	102	4.65
96	28	29	3.24
97	28	82	7.10
98	28	86	4.32
99	28	87	3.90
100	28	90	6.10
101	29	31	4.05
102	29	81	2.89
103	29	82	4.26
104	31	32	3.15

contd....

TABLE 3.6 (contd.)

LINK NO.	NODES AT	ENDS	RIDING TIME
105	31	73	4.64
106	32	33	6.74
107	32	57	3.54
108	32	75	3.41
109	32	78	2.74
110	32	81	2.21
111	32	95	4.13
112	33	41	8.81
113	33	64	11.50
114	33	65	5.68
115	33	78	5.57
116	33	140	13.14
117	34	39	3.38
118	34	40	5.13
119	34	41	4.32
120	34	50	5.93
121	35	36	5.55
122	39	40	2.69
123	40	41	5.70
124	40	50	5.50
125	40	60	4.96
126	40	106	6.24
127	41	50	5.36
128	41	106	2.20
129	42	43	3.53
130	42	56	5.35
131	42	58	7.64
132	43	44	3.14
133	43	45	4.05
134	43	58	3.73
135	44	46	7.21
136	45	56	3.68
137	45	58	3.27
138	45	62	2.80
139	46	47	6.74
140	46	59	2.38
141	47	48	8.70
142	47	59	8.49
143	47	62	16.00
144	48	117	13.35
145	49	60	4.15
146	50	51	2.83
147	50	57	6.17
148	50	60	3.65
149	50	103	4.40
150	50	106	4.34
151	51	52	2.96
152	51	53	4.88
153	51	61	4.69
154	51	103	4.76
155	51	135	6.43
156	52	53	5.39

contd...

TABLE 3.6 (contd.)

LINK NO.	NODES AT	ENDS	RIDING TIME
157	52	57	5.57
158	52	97	2.00
159	52	109	2.56
160	53	57	5.24
161	53	96	3.27
162	53	97	1.00
163	53	108	5.39
164	53	109	3.26
165	53	130	4.61
166	54	138	3.32
167	55	56	2.59
168	55	62	3.71
169	55	112	3.32
170	56	62	4.40
171	57	103	4.78
172	58	59	7.98
173	58	76	3.68
174	59	76	3.05
175	59	120	7.29
176	60	61	4.38
177	60	136	2.27
178	61	135	4.60
179	61	136	3.49
180	62	63	6.99
181	62	74	4.33
182	63	117	11.30
183	64	65	6.25
184	64	139	4.60
185	66	75	2.42
186	66	86	2.67
187	66	95	1.16
188	67	68	5.25
189	68	69	8.69
190	68	72	4.90
191	70	71	5.55
192	70	78	2.49
193	72	73	2.92
194	72	141	4.64
195	73	88	8.86
196	75	95	1.21
197	76	114	2.89
198	76	120	5.99
199	78	80	12.20
200	79	82	2.55
201	79	88	1.55
202	81	82	9.06
203	81	86	3.16
204	81	137	2.15
205	82	83	4.81
206	82	89	1.87
207	82	90	4.25
208	82	98	6.04

contd...

TABLE 3.6 (contd.)

LINK NO.	NODES AT	ENDS	RIDING TIME
209	83	84	3.99
210	83	104	3.38
211	84	85	3.20
212	84	100	2.65
213	84	101	3.47
214	84	102	3.30
215	85	101	3.70
216	86	87	2.82
217	86	93	6.05
218	87	137	3.29
219	88	137	2.44
220	89	90	3.99
221	89	98	6.40
222	89	102	11.82
223	90	93	2.60
224	90	104	4.26
225	91	92	4.46
226	91	137	5.11
227	93	94	3.03
228	94	95	2.34
229	96	108	5.81
230	99	100	3.19
231	99	102	2.49
232	99	110	3.27
233	100	105	6.41
234	102	105	7.23
235	107	108	3.03
236	107	119	4.87
237	109	135	11.18
238	110	111	4.43
239	110	120	6.76
240	111	142	2.61
241	112	113	1.86
242	113	119	8.44
243	113	138	4.40
244	117	118	1.23
245	117	138	7.64
246	120	121	5.32
247	120	125	4.76
248	121	122	11.82
249	121	123	5.73
250	121	124	8.56
251	121	132	7.66
252	122	123	7.38
253	122	132	1.93
254	123	124	3.76
255	123	132	5.47
256	130	133	4.05
257	130	134	8.26

unit time on a link i. The objective function is

Minimize

$$Z_1 = (\sum_i (RT_i)(LKFLOW)_i + \sum_i RT_i (NOBUS)_i \; W) \qquad (3.9)$$

subject to all demand of travel matrix is satisfied.

where

W = Value of vehicle time compared to riding time of passenger.

$(NOBUS)_i$ and W are to be estimated using the available data of the bus transit system.

3.6.2 Estimation of Parameters

(a) Number of Bus Trips on a Link: The number of trips to be made in a unit time on a link i i.e. ($(NOBUS)_i$) depends upon the passenger flow on that link ($(LKFLOW)_i$). Some studies (Scott, 1969; Rea , 1971) indicate that ($(NOBUS)_i$) is directly proportional to the square root of passengers on a link. In the absence of any such like relationship for the Indian cities, the following procedure is adopted to establish the relationship:

(i) The average link flow of passengers on a route for all the 191 routes as obtained in Section 3.4 is related with the existing number of bus trips on that route.

(ii) The regression analysis is carried out for all the 191 routes and the following relationship is estimated.

$$(NOBUS)_i = 0.137 \; ((LKFLOW)_i)^{0.795} \qquad (3.10)$$

$$(R^2 = 0.88)$$

where

$(NOBUS)_i$ = Number of bus trips to be made in a unit time on a link i.

$(LKFLOW)_i$ = Flow of passengers in unit time on link i.

(b) Value of Vehicle Time Compared to Passenger Riding Time (W): To get the value of W, passenger riding and vehicle operating cost are calculated. Riding time cost can be determined using indifference curves (or utility theory) for the set of passengers under consideration. In that case surveys have to be conducted to establish the riding time cost models. But such detailed analysis is not made and it is assumed that the captive users with the income range of Rs. 7200.00 to Rs. 9600.00 per annum are constituting the demand for bus transit. To be conservative a sum of Rs. 7200.00 per annum is taken as the basis for calculating the monetary value of time. Assuming 25 working days in a month and 8 working hours per day, the value of time is thus Rs. 3.00 per hour.

The operating cost of a vehicle (including capital cost) is taken as Rs. 2.5 per vehicle kilometre (Namballa, 1982) i.e. KMCOST = Rs. 2.5 for a bus with 60 seat capacity.

The kilometres travelled by a bus per hour (BUSKMH) considering all the 191 routes are calculated using two criteria: (i) with consideration of the service time at the stops of a route (ii) without consideration of service time at the stops of a route (i.e. bus goes directly from origin to terminal). The values of BUSKMH are shown in Table 3.7.

TABLE 3.7 : AVERAGE OPERATING SPEED OF BUSES IN AHMEDABAD

Sl. No.	Criteria	Mean value of (BUSKMH)KMS	Median Value of (BUSKMH)KMS
1	Service time considered	16.51	15.93
2	Service time not considered	17.93	16.99

With these four values of BUSKMH, the four values of W are calculated as follows:

$$W = (BUSKMH) * (KMCOST) / (VT) \qquad (3.11)$$

where

BUSKMH = Kilometres travelled by a bus in one hour.

KMCOST = Operating cost of a vehicle(bus) per bus kilometre.

VT = Value of riding time (i.e. Rs.3/hr.).

From the values of W, the mean value of W is taken as 15. This indicate that the value of vehicle time is 15 times that of the passenger riding time.

3.6.3 Minimizing the objective function

The objection function Eqn. 3.9 can be written as

$$\sum_i (RT)_i (LKFLOW)_i + \sum_i (RT)_i . (0.137)\ (LKFLOW)^{0.795} . (15) \tag{3.12}$$

after substituting the values of $((NOBUS)_i)$ i.e. $0.137((LKFLOW)_i)^{0.795}$ and W i.e. 15 from the Equations 3.10 and 3.11 respectively so, the objective function is

$$Z_1 = \underset{\text{Minimize}}{\sum_i} (LKFLOW)_i\ (RT)_i\ \left(1 + \frac{1.0275}{((LKFLOW)_i)^{0.205}}\right) \tag{3.13}$$

$$= \sum_i (LKFLOW)_i\ T_i^*$$

where

$$T_i^* = (RT)_i\ \left(1 + \frac{1.0275}{(LKFLOW)_i^{0.205}}\right) \tag{3.14}$$

To obtain the minimum value of the nonlinear objective function (Eqn. 3.13) defined earlier the heuristic algorithm given in section 2.6.2 is used. As described earlier, backward approach (i.e. deleting links from a fine meshed network) appear to give better results than the forward approach (i.e. adding links to the minimal spanning tree). For the case study network, a backward approach is chosen. To start with all the 514 links are taken and then proceed towards to the coarse-meshed one (402 links). For this case study, four networks are tested. The heuristic algorithm is used for each of the four different networks to obtain the total cost in terms of time. A brief summary of this algorithm as applied to the networks is as follows:

(i) The shortest paths for all the origin-destination pairs are obtained. In the first iteration, only riding time (RT_i) is considered but in subsequent iterations the sum of riding and vehicle time(as revised in the subsequent steps) i.e. T_i^* is used. Using the shortest paths, all the link flows $(LKFLOW)_i$ are estimated for the given O-D matrix.

(ii) The time (T_i) to tranerse a link i is revised(T_i^*) based on the link flow($(LKFLOW)_i$) using the following relationship:

$$T_i^* = (RT)_i * \left(1 + \frac{1.0275}{(LKFLOW)_i^{0.205}}\right).$$

(iii) The revised time T_i obtained in Step (ii) is used to find the shortest paths for all the O-D pairs and revised value of the link flow $(LKFLOW)_i^*$ is obtained.

(iv) Compute the total link time i.e. $LT_i = (T_i)^* (LKFLOW_i^*))$ and total time for the network i.e. $TLT = \sum_i (T_i)^* ((LKFLOW)_i^*$.

(v) If any of the link time (i.e. LT_i) or total link time (TLT) gets changed in Step (iv) then the procedure is repeated starting with Step (ii) otherwise it is stopped.

The above procedure is repeated for all the four different networks and it is observed that generally about four iterations need to be performed for each of the network to obtain the convergence of the total link time. As the network is quite large for the case study only one iteration is performed in one run of the experiment. The results obtained from an iteration are given as the input for the next iteration. The CPU time on DEC 1090 system for the iteration of a network is about 4 minutes. 16 different runs are made and the results are shown in Table 3.8. For the network number 2, 3 and 4 those links

having much less flow are deleted. The results indicate that by deleting some links from the starting network (no. 1 having 514 links), the total time gets reduced upto a certain stage and then starts increasing. The results indicate that the minimum time is for the network number 3 having 426 links. This network is considered for the further analysis.

TABLE 3.8 : CONCENTRATION OF PASSENGER FLOWS IN ALTERNATIVE NETWORKS

Sl. No.	Number of links in a net-work	ITERATION 1	2	3	4
		Total riding time	Total (riding+ vehicle) time	Total (riding+ vehicle) time	Total (riding + vehicle) time
1	514	11897919	13704568	13718200	13720158
2	492	11898220	13705189	13718554	13720282
3	426	11903306	13723576	13717526	13717565
4	402	11954794	13773298	13767130	13773238

3.7 Generation of Routes

3.7.1 General

The model specifies that a large set of all possible routes be generated and then optimal ones alongwith their

frequencies be selected using Linear Programming, so that the number of transfers saved are maximized. For a large network as taken in this study, theoritically there may be a very large number of possible routes between every O-D pair, but some of which may not be feasible. Rather than eliminating the nonfeasible routes at a latter stage, an heuristic procedure is developed to generate sufficiently large number of routes which satisfy certain practical constraints. The following requirements are specified:

(i) The length of the route should not be less than 2.0 kms as otherwise it may result in concentration of the buses in some sections of the network.

(ii) The path of the route between two terminating stations should not meander excessively from the shortest path. The length of the path of a route should not be greater than the twice the shortest distance between the termini.

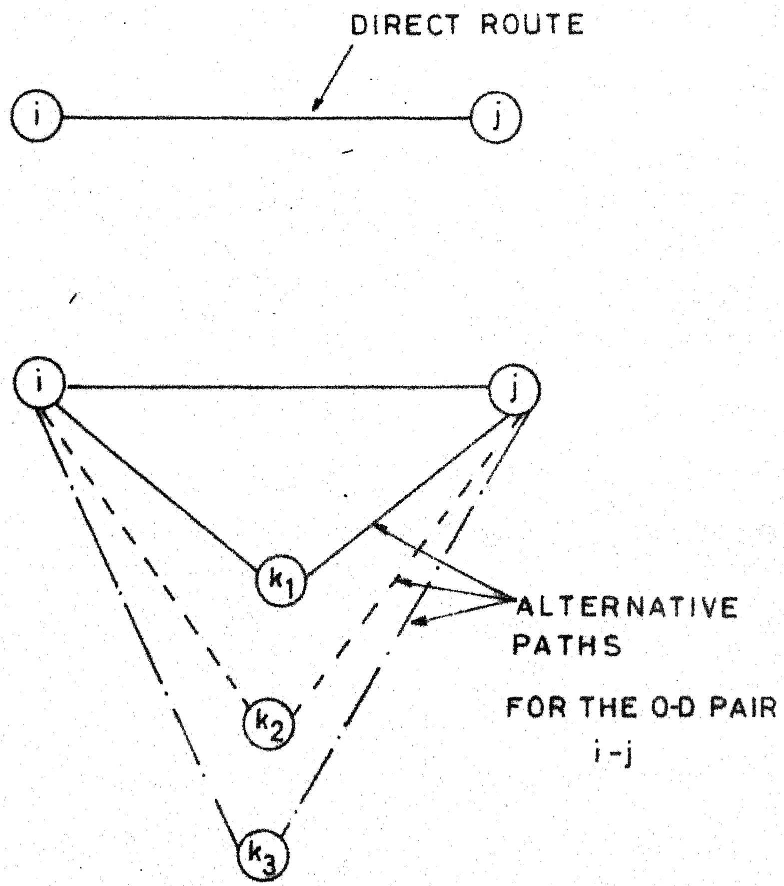
(iii) There should not be any backtracking on the route.

In cases where there are a number of intermediate stations on the shortest path between two termini, there may be a very large number of alternative paths which may be formulated. It is desirable that the nodes inserted in between be selected rationally without leaving the combinations that satisfy the basic requirements. If all

connected by a link i-j. Alternative paths for this route between i and j can be found out by inserting the intermediate nodes (say k) such that path i-k-j satisfies the requirements namely the length of the path i-k-j is less than twice the shortest distance between nodes i and j (Fig. 3.3). In this way all possible intermediate nodes K ($k_1, k_2, \ldots$) that can be inserted are analyzed and all the resulting routes between i and j are used while generating the routes between the distant termini.

(ii) The O-D pairs not directly connected are divided into various groups according to the shortest distance through them. In this study, the O-D pairs are divided into 9 different groups starting with 1.5 Kms. and ending with 20 Kms. The generation of the routes is first done for the closer O-D pairs and then expanded by using the information of already generated routes. In one experiment run one group is taken for the generation.

(iii) For a given group of O-D pairs the alternative paths of the route are generated as follows: Let i-j be the O-D pair having stops $i_1, i_2, i_3, \ldots$ etc.



IF SD(i,k)+SD(k,j) $\not>$ 2·0 * SD(i,j) THEN NODE k ($k=k_1,k_2,k_3$ - - - -) IS INSERTED OTHERWISE NOT.

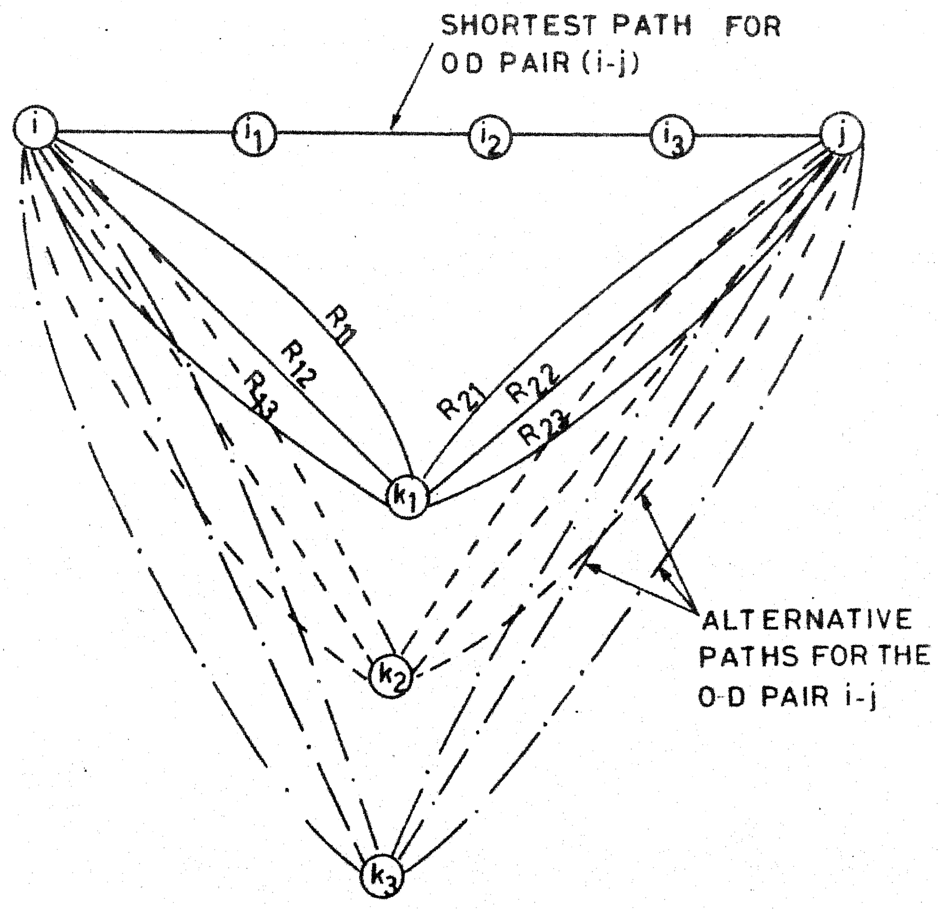
FIG.3·3 ALTERNATIVE PATHS FOR DIRECTLY CONNECTED O-D PAIR.

on the shortest path between them. Let K_1 be the node to be inserted such that the shortest path between i and j via K (i.e. SD(i,K) + SD(K,j)) is less than 1.5 times the shortest distance between i and j (SD(i,j)). All the previously established routes between i and k_1 (i.e. R_{11},R_{12}, R_{13},.....) and between k_1 and j (i.e. R_{21},R_{22},R_{23},...) are considered (Fig.3.4). All the combinations of the routes between i to k_1 and k_1 to j are analyzed such that the total length of the selected path between i to j does not exceed twice the shortest distance between i and j.

This procedure is repeated for all the possible intermediate nodes (i.e. k_1,k_2,k_3,.....) to be inserted and all the feasible routes are stored.

(iv) The above procedure (i.e. step iii) is repeated for all the O-D pairs of a group.

(v) As the distance between the O-D pair increases it is not appropriate to select all the O-D pairs as terminals and those having less demand may be neglected as otherwise it considerably increases the computation. For the O-D pairs which are more than 7 kms. away and have trip distribution of less than 500 passengers per day are not considered in generation of routes at this stage. The procedure



IF $SD(i,k)+SD(k,j) \not> 1.5 * SD(i,j)$
THEN NODE $k(K=k_1,k_2,k_3$ - - - - $)$ IS
INSERTED OTHERWISE NOT.

FIG. 3·4 ALTERNATIVE PATHS FOR NOT DIRECTLY CONNECTED O-D PAIR.

given in steps (iii) to (v) is repeated for all the groups.

(vi) All the routes generated are used to find if any traffic demand for a O-D pair is left out. If it is so, new routes are generated between these O-D pairs.

In a nutshell, the procedure is as follows:

(a) Routes are first generated for the O-D pair which have direct links.

(b) The O-D pairs which are not directly connected are divided into various groups according to shortest distance between them. The generation of routes is done by first analyzing closer O-D pairs and then expanding for distant O-D pairs (shortest distance less than 7 kms.).

(c) The node (K) is inserted between the O-D pair(i-j) such that the distance of the selected path i-k-j **does not** exceed twice the shortest distance between i and j.

(d) For distant O-D pairs (shortest distance greater than 7 kms.), only major O-D pairs are selected for route generation. Alternative paths between these pairs are generated.

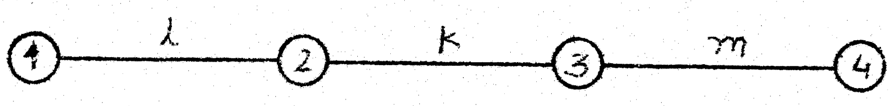
(e) New Routes are generated for the unsatisfied demand of the O-D pairs.

The heuristic procedure gives 457 possible routes for the network, the path of these routes and their lengths are given in Appendix III.

3.8 Transfers Saved on a Route

The model evaluates the generated set of routes in previous section by the criterion of maximum number of transfers saved by a route through a LP formulation. So for each node of a route, turning flow between the links and the number of transfers saved for this turning flow is needed. The total number of transfers saved by a route is the sum of the transfers saved by each node of a route.

The number of transfers saved per route trip is calculated in the following way:



Let the path of a route be represented by the nodes 1, 2, 3 and 4 and links l, k and m as shown above. Let

$(TURNFL)_{lk}$ be the number of passengers per day going directly from link l to link k or vice versa. The estimated number of bus trips per day is $(NOBUS)_l$ on link l. If a route goes directly from link l to link k the number of transfers saved per route trip for this route and this turning flow, is estimated by following relationship:

$$(NOTRAN)_{pr} = \frac{(TURNFL)_{lk}}{\text{Minimum}\left\{(NOBUS)_l, (NOBUS)_k\right\}} \qquad (3.15)$$

where

$(NOTRAN)_{pr}$ = Number of transfers saved for p^{th} turning flow of route r.

$(TURNFL)_{lk}$ = Number of passengers travelling from link l to link k or vice versa.

$\text{Minimum}\left\{(NOBUS)_l, (NOBUS)_k\right\}$ = The minimum value of the number of bus trips on the two links l and k.

The various steps for calculating the number of transfers saved by a route trip are as follows:

(i) Calculate the turning flow at a node i ($(TURNFL)_{lk}$) i.e. the number of passengers per day going directly from link l to link k or vice versa by the following relationship:

$$(TURNFL)_{lk} = \sum_{t=i+1}^{NONODS} \sum_{s=1}^{i-1} (JFLOW(s, t)) \qquad (3.16)$$

where

JFLOW(s,t) = Flow of passengers between the O-D pair s-t.

i = Node of a link where links l and k intersect.

NONODS = Number of nodes in a route.

(ii) Estimate the number of bus trips in each direction on the links of a route using the following relationship:

$$(NOBUS)_l = 0.137 \; ((LKFLOW)_l)^{0.795} \qquad (3.17)$$

The link flow on link l i.e. $(LKFLOW)_l$ connecting the nodes i and j, is found out by following relationship:

$$(LKFLOW)_l = \sum_{t=i+1}^{NONODS} \sum_{s=1}^{i} JFLOW(s,t) \qquad (3.18)$$

The value of JFLOW(s,t) is obtained from the O-D matrix.

(iii) After getting the values of $(TURNFL)_{lk}$ and $(NOBUS)_l$ from the steps (i) and (ii) respectively, the number of transfers saved at each node of a route is estimated by the Eqn. 3.15.

(iv) The number of transfers saved is calculated for each turning flow along the route and added to the total for the route, to obtain the total number of transfers saved by a route $(TTRAN)_r$.

In a nutshell, the procedure is as follows:

(1) All turning flows are found out along the route using O-D matrix.

(2) The number of bus trips on each link is estimated using the relationship between link flow and the number of bus trips. The link flow is found by using O-D matrix.

(3) The number of transfers saved for each turning flow per route trip is found out as the ratio of the turning flow and the minimum number of bus trips on the two links which intersect at the node.

(4) The total number of transfers saved by a route $(TTRAN)_r$ is found out by summing the transfers saved for each turning flow along the route.

The above procedure is used for the network for the case study and number of transfers saved by each of the 457 routes are obtained. For each route, the transfers saved are calculated along the route and added to get the total number of transfers saved. Then all turning movements on the network are identified. The different values of the p^{th} turning movement are obtained for various routes. From these, the maximum value of the p^{th} turning movement is found out. For this network 421 turning movements and

their maximum values are found out. The number of transfers saved by each route in shown in the Appendix III.

3.9 Maximum Frequency on a Route

For the LP problem formulation, described in the Chapter 2, the maximum frequency i.e. $(\mathrm{MAXFRE})_r$ is required for every route for the constraint set of equations. The bus trips on every link of a route is estimated using Eqn. 3.9 and maximum frequency of the route is estimated.

3.10 Simultaneous Choice of Routes and Frequencies

In the preceding phases passengers have been assigned paths considering passenger riding time cost and operation cost. A set of interesting routes (457) has also been generated. In this phase optimal set of routes and their frequencies are obtained such that as many transfers as possible are avoided. The problem is formulated and solved as a linear-programming problem(LP).

The objective function as described in Chapter 2 is

$$\text{Maximize } Z = \sum_{r=1}^{NR} (\mathrm{TTRAN})_r \, (\mathrm{FREQ})_r \tag{3.19}$$

subject to four sets of constraints

$$\text{(i)} \quad \sum_{r=1}^{NR} (\mathrm{NOTRAN})_{pr} . (\mathrm{FREQ})_r \leq (\mathrm{MAXTFL})_p \qquad \forall p \tag{3.20}$$

$$\text{(ii)} \quad \sum_{r=1}^{NR} (\mathrm{RTTIME})_r . (\mathrm{FREQ})_r \leq (\mathrm{OT}) . (\mathrm{OPF}) \tag{3.21}$$

(iii) $0 \leq (FREQ)_r \leq (MAXFRE)_r$ $\quad \forall_r$ (3.22)

(iv) $(NOTRN)_p \geq 0$ $\quad \forall_p$ (3.23)

where

$(NOTRAN)_{pr}$ = Number of transfers saved for $p^{\underline{th}}$ turning flow of route r.

$(FREQ)_r$ = Frequency on route r

$(TTRAN)_r$ = Total number of transfers saved by a route r.

NR = Number of routes in a network

$(MAXTFL)_p$ = Maximum value of the turning flow for the $p^{\underline{th}}$ turning movement.

$(RTTIME)_r$ = Round trip time on route r.

$(MAXFRE)_r$ = Maximum frequency of route r.

$(NOTRN)_p$ = Number of transfers saved for the $p^{\underline{th}}$ turning flow.

OPF = Operating fleet size.

OT = Operating time in hrs.

For the case study network, 457 routes have been generated and 421 turning movements (flows) are indentified. This results into 879 constraint equations. For the LP solution the work vector dimension requirement is

(M1 + M2 + 2) * (M1 + M2 + 2) + 3* M1+ 2*M2+4 where M1 is the number of inequality constraints (=879) and M2 is the number of equality constraints. Beside work vector

dimension, other memory storage is also required for the coefficient matrices and resource vector. It is found that the available 'DEC-1090 SYSTEM' is not in a position to handle the solution of LP of such a large magnitude due to the core capacity. To tackle this problem, LP solution is done in parts by dividing the network into seven distinct parts keeping in mind the interaction of the various parts.

For the case study network, the values of $(NOTRAN)_{pr}$, $(TTRAN)_r$, $(MAXTFL)_p$ and $(MAXFRE)_r$ are already calculated in the previous sections for all the 457 routes.

The $(RTTIME)_r$ i.e. round trip time on a route r is calculated by the following formula:

$$(RTTIME)_r = \frac{(TRL)_r}{AVERSP} + (LOT)_r \qquad (3.24)$$

where

$(TRL)_r$ = Total route length (Kms.)

AVERSP = Average speed of the bus (Kmph.)

$(LOT)_r$ = Lay over time at the destination of a route r.

The average speed of the bus is estimated using the values of different speeds in different areas of the city. The speeds of the bus are in the range of 5-10 Kmph, 10-20 Kmph. and 20-25 Kmph for walled city, intermediate and peripheral and outlying areas respectively. So, the average

speed of the bus is taken as 15 Kmph.

The lay over time at the destination of a route is estimated taking into consideration the route length. For a route length less than 5 Kms., 5-15 Kms. and greater than 15 Kms., the lay over time is taken as 5 min, 10 min and 15 min respectively.

The constraint set (ii) makes use of the operating fleet size. Experiment runs are made with three different operating fleet sizes (670, 750, 790). The total fleet of the network is divided among the various parts of the network in proportion with the maximum frequency and round trip time of the routes contained in the part of the network, and it is given as the input to the experimental run.

From the optimal set of routes for each fleet size, the routes having frequency less than 18 (i.e. headway greater than one hour) are deleted. The final set of optimal routes and their frequencies as obtained for the total fleet size of 670 is given in Table 3.9.

3.11 Analysis of Results

For the fixed O-D matrix of Ahmedabad, the model generates 426 links on the network on which the passenger flow can be concentrated so as to minimize the total cost (Riding time cost + Operating vehicle cost). The network

TABLE 3.9 (part 1): PATHS OF OPTIMAL BUS ROUTES FOR AHMEDABAD (OPERATING FLEET = 670)

ROUTE NO	ROUTE LENGTH	NODES	TOUCHED	BY	THE	ROUTE	
1	2.10	11	5	41	106		
2	2.50	58	43	45	62		
3	2.10	11	5	41	106		
4	3.00	12	11	6	5	41	
5	2.50	14	7	8	114		
6	2.40	53	96	22	108		
7	3.00	93	86	66	95		
8	3.10	100	84	102	99	110	
9	2.70	1	13	66	95		
10	3.00	4	3	10	57	5	
11	2.00	7	14	15			
12	2.50	10	5	11	41		
13	2.60	32	75	95	66	86	
14	2.60	32	95	66	86		
15	2.00	32	75	95	94		
16	2.60	43	45	62	56		
17	3.60	56	62	45	43	59	
18	2.60	66	75	95	32	81	
19	2.60	75	95	66	86	81	
20	3.30	75	95	66	86	93	
21	2.00	86	66	95	94		
22	2.90	93	27	102	99		
23	3.20	1	2	3	10	4	
24	3.20	1	13	66	86		
25	3.90	1	13	66	95	75	86
26	2.80	4	3	5	41		
27	2.70	4	10	5	41		
28	3.20	4	9	42	43		
29	2.50	7	8	14	15		
30	2.80	10	57	52	97	53	
31	2.30	11	6	19			
32	2.90	11	12	33	19		
33	3.40	17	39	34	41		
34	2.40	42	43	45	62		
35	3.30	42	43	58	45	62	
36	2.40	45	62	63			
37	2.60	66	86	93			
38	2.70	66	86	81	137		
39	2.10	87	137	91			
40	2.30	99	100	84	101		

Contd......

TABLE 3.9 (part 1): (Contd.)

ROUTE NO	ROUTE LENGTH	NODES TOUCHED BY THE ROUTE										
41	2.50	99	100	105								
42	2.80	99	110	120								
43	2.90	112	113	119								
44	3.30	1	66	95	75	32						
45	4.00	1	13	66	95	32						
46	4.00	1	2	3	4	10	57					
47	3.90	1	2	3	5	57						
48	3.00	1	2	3	10	57						
49	4.70	1	13	66	95	75	86	87				
50	5.60	1	13	66	95	75	86	93				
51	4.00	4	3	5	6	11	12					
52	3.10	10	57	20	53	130						
53	3.10	12	33	32								
54	3.50	26	99	110	120							
55	3.10	86	81	137	91							
56	3.40	110	120	125								
57	5.00	1	12	33	19	18						
58	4.90	1	2	3	4	24						
59	5.50	1	2	3	5	41	34					
60	6.30	1	2	3	5	50	60					
61	4.40	1	13	7	26	99						
62	7.50	1	13	66	95	75	86	93	26	99		
63	6.40	12	11	6	5	41	34	39	17			
64	4.20	66	95	94	93	90	82					
65	4.00	120	121	132	122							
66	5.80	1	12	11	6	19	18					
67	5.70	1	2	3	4	42	43	45				
68	6.60	1	2	3	4	42	56	45				
69	5.80	1	66	95	94	93	90	82				
70	5.30	1	13	7	26	99	110					
71	7.40	4	3	2	1	12	11	41	40	17		
72	3.80	4	3	2	1	12	11	6	5	41	40	17
73	5.90	4	3	2	1	66	95	75	32			
74	5.90	4	3	2	1	66	95	32				
75	6.50	4	3	2	1	12	33	32				
76	6.30	10	3	2	1	12	33	32				
77	8.60	1	2	3	4	9	8	114	76	120		
78	6.30	1	13	7	26	110	120					
79	6.20	1	12	33	19	64	139					
80	5.40	1	13	7	8	9	4					

Contd.....

TABLE 3.9 (part 1): (Contd.)

ROUTE NO	ROUTE LENGTH	NODES TOUCHED BY THE ROUTE																		
81	4.20	4	10	5	11	12	1													
82	8.40	4	9	8	7	26	27	28	29	31	32									
83	9.33	4	9	8	7	26	93	90	89	82	79	88								
84	8.75	88	137	81	32	33	6	5	10	4										
85	6.85	1	66	95	94	26	99	110	111											
86	12.30	17	39	34	19	6	11	12	1	30	8	7	26	99	110					
87	19.75	17	40	39	34	41	5	11	12	1	30	8	7	26	99	110	120	121	123	122
88	12.50	1	66	95	94	26	99	110	120	121	123	124								
89	3.40	110	120	125																
90	3.40	110	120	125																
91	14.00	68	67	32	95	94	26	99	110	120	121	122								
92	16.11	122	132	121	120	110	99	26	7	8	114	76	58	45	62	63				
93	9.34	71	70	78	32	95	94	26	7	14	15									
94	10.10	1	30	8	114	76	59	46	47	48										
95	10.16	59	76	114	8	77	4	24	23	107	21									
96	7.80	1	30	9	42	58	45	56	55											
97	5.50	1	30	9	42	56	55													
98	7.20	11	5	10	4	42	58	45												
99	6.55	4	42	58	45	62	63													
100	10.40	63	62	55	56	42	4	10	57	20	53	130								
101	11.14	140	33	12	11	5	10	4	42	43	45	62	55							
102	10.15	88	79	82	90	93	26	7	8	9	42	56	55							
103	8.45	1	25	77	4	54	138	117												
104	10.40	1	12	11	5	10	4	54	138	117	118									
105	7.35	22	53	57	10	5	11	12	1											
106	9.45	22	24	4	9	8	7	13	1											
107	7.80	1	25	77	4	24	96	108												
108	12.80	22	96	24	4	9	8	7	26	93	90	82	79	88						
109	11.15	24	4	9	8	7	26	99	102	89	82									
110	10.35	1	12	11	5	57	52	53	130	133										
111	14.30	82	90	93	86	66	1	12	11	5	57	52	53							
112	6.85	1	25	77	4	10	57	52	53											
113	5.65	10	57	20	53	130	134													
114	5.10	4	10	57	20	53	22	108												
115	5.30	10	57	52	109	135														
116	9.55	1	80	6	19	34	39	40	17	49										
117	9.10	1	12	33	41	106	40	60	49											
118	11.35	49	60	50	41	5	10	4	42	56	62	63								
119	7.30	1	12	11	6	19	64	139												
120	8.40	1	12	11	6	19	34	18	35	36										

contd.....

TABLE 3.9 (part 1): (Contd.)

ROUTE NO	ROUTE LENGTH	NODES TOUCHED BY THE ROUTE														
121	7.80	10	3	5	6	19	18	35	36							
122	6.40	1	12	33	65	64	139									
123	6.50	10	5	6	19	64	139									
124	7.65	1	66	95	75	32	31	73	72	141						
125	6.45	110	120	121	124											
126	11.35	17	40	34	41	5	10	4	54	138	117					
127	6.60	1	12	11	5	41	50	60	136							
128	11.50	21	107	23	24	4	77	25	13	7	14	15				
129	8.80	1	12	11	6	19	34	18	35	36						
130	6.10	17	39	40	41	5	3	4								
131	13.80	17	39	40	50	51	52	109	53	23	24	112	55	56	45	
132	7.50	4	3	5	65	64										
133	12.10	17	18	19	6	5	10	4	9	7	14	15				
134	7.50	38	17	39	40	41	5	10	4							
135	16.95	38	17	39	40	41	5	10	4	42	43	44	46	47	48	
136	9.00	49	18	34	19	6	5	10	4							
137	4.15	10	5	6	65											
138	12.15	17	39	34	41	5	11	12	1	66	75	32	67	68		
139	13.60	72	73	31	32	75	66	1	30	9	42	43	45	62	74	
140	15.20	32	75	66	13	7	14	15	16	76	59	58	45	62	63	
141	14.80	68	67	32	75	66	1	12	11	5	10	4	24	23	107	21
142	8.40	4	10	5	11	12	33	78	70	71						
143	8.10	68	67	32	33	6	5	10	4							
144	14.30	68	67	32	75	95	66	1	25	77	4	42	43	45	62	63
145	5.80	1	25	77	4	42	43	44								
146	9.55	4	3	2	12	33	32	31	73	72						
147	6.50	4	3	2	12	33	32									
148	12.65	17	40	39	34	19	33	32	31	73	88	79	82			
149	8.40	4	77	25	1	66	86	87	137	91						
150	12.60	88	79	82	89	90	93	26	7	8	114	76	59	47		
151	13.50	17	40	34	19	6	11	12	1	66	86	87	28	82		
152	7.75	82	28	86	66	1	12	33								
153	9.85	4	77	25	1	66	86	93	90	89	82					
154	12.50	17	39	34	41	5	11	12	1	66	86	93	90	82		
155	14.25	17	18	19	6	11	12	1	30	8	7	26	99	100	84	101
156	7.90	1	66	86	28	27	84	101								
157	7.20	1	66	95	94	26	99	102	84	85						
158	7.15	1	66	95	94	26	99	102	105							
159	5.70	4	9	8	7	26	27	102								
160	7.50	4	9	8	7	26	27	83	104							

TABLE 3.9 (PART II) : CHARACTERISTICS OF OPTIMAL BUS ROUTES
(OPERATING FLEET = 670)

ROUTE NO.	NO. OF ~~BUSES~~ TRIPS PER DAY	ROUND TRIP TIME (MIN.)	NO. OF BUSES REQD.
1	54	21.8	2
2	29	25.0	1
3	54	21.8	2
4	102	33.6	4
5	28	25.0	1
6	26	24.2	1
7	47	33.6	2
8	25	34.4	1
9	51	31.2	2
10	125	33.6	4
11	23	21.0	1
12	49	25.0	2
13	35	30.4	1
14	57	30.4	2
15	55	21.0	2
16	27	30.4	1
17	25	38.4	1
18	35	30.4	1
19	25	30.4	1
20	35	36.0	2
21	39	21.0	1
22	20	32.8	1
23	256	35.2	9
24	84	35.2	3
25	71	40.8	3
26	54	32.0	2
27	82	31.2	3
28	57	35.2	2
29	62	25.0	2
30	95	32.0	3
31	35	23.4	1
32	57	32.8	2
33	46	36.8	2
34	69	24.2	2
35	64	36.0	3
36	81	24.2	2
37	46	30.4	2
38	51	31.2	2
39	27	21.8	1
40	80	23.4	2
41	52	25.0	2
42	77	32.0	3
43	28	32.8	1
44	192	36.0	7
45	95	41.6	4
46	141	41.6	6
47	19	40.8	1
48	23	33.6	1
49	35	47.2	2
50	27	51.4	2
51	85	41.6	4
52	134	34.4	5
53	31	34.4	1

Contd......

TABLE 3.9 (PART II) (CONTD.)

ROUTE NO.	NO. OF ~~BUSES~~ TRIPS PER DAY	ROUND TRIP TIME (MTN.)	NO. OF BUSES REQD.
54	19	37.6	1
55	20	34.4	1
56	54	36.8	2
57	28	49.6	2
58	87	48.8	4
59	49	53.6	3
60	43	60.0	3
61	109	44.8	5
62	99	65.0	6
63	224	60.8	13
64	53	43.2	3
65	51	41.6	2
66	40	56.0	3
67	20	55.2	2
68	71	67.4	5
69	70	56.0	4
70	29	52.0	2
71	152	68.8	10
72	87	85.4	7
73	120	56.8	7
74	64	56.8	5
75	60	61.6	4
76	48	60.0	3
77	81	83.8	7
78	58	60.0	4
79	24	59.2	2
80	310	52.8	16
81	340	43.2	14
82	50	82.2	4
83	83	89.6	7
84	75	85.0	6
85	22	64.4	2
86	111	113.4	12
87	93	173.0	15
88	29	115.0	4
89	41	36.8	2
90	54	36.8	2
91	45	127.0	6
92	38	143.9	6
93	28	89.7	3
94	42	95.8	4
95	38	96.3	4
96	53	77.4	4
97	32	53.6	2
98	41	67.2	3
99	33	62.0	2
100	104	98.2	10
101	67	104.1	7
102	33	96.2	3
103	170	82.6	13
104	65	98.2	6
105	30	68.4	2
106	72	90.6	7

contd....

TABLE 3.9 (PART II) (CONTD.)

ROUTE NO.	NO. OF ~~BUSES~~ TRIPS PER DAY	ROUND TRIP TIME (MIN.)	NO. OF BUSES REQD.
107	64	77.4	5
108	67	117.4	10
109	33	104.2	4
110	27	97.8	3
111	21	129.4	3
112	69	64.4	6
113	28	54.8	2
114	75	50.4	4
115	27	52.0	2
116	21	91.4	2
117	38	87.6	4
118	28	105.8	3
119	31	68.0	2
120	27	82.2	3
121	34	77.4	3
122	73	60.8	5
123	51	61.6	3
124	71	76.2	5
125	19	61.2	2
126	88	105.8	9
127	101	62.4	6
128	54	107.0	6
129	54	85.4	5
130	107	58.4	6
131	44	125.4	6
132	25	65.0	2
133	50	111.8	6
134	80	65.0	5
135	37	150.6	6
136	22	87.0	2
137	21	42.8	1
138	165	112.2	19
139	25	123.8	3
140	29	136.6	4
141	94	133.4	12
142	32	82.2	3
143	24	79.8	2
144	85	129.4	11
145	38	56.0	2
146	62	91.4	6
147	19	61.6	2
148	33	116.2	4
149	18	82.2	2
150	120	115.8	3
151	109	123.0	13
152	85	77.0	7
153	54	93.8	5
154	34	115.0	4
155	95	129.0	12
156	39	78.2	3
157	60	67.2	4
158	43	56.8	3
159	27	55.2	2
160	52	65.0	4

consisting of these 426 links (213 links in each direction) and 134 nodes is used to generate the feasible routes that satisfy the basic requirements of the route and meet the demand. In all 457 routes are generated. The LP model is used to obtain the optimal set of routes and the simultaneous choice of their frequencies for a given fleet size.

The optimal routes and their frequencies are obtained for seven different zones and for the entire network using 3 different operating fleet sizes (670,750, 790) for the network. The summary of the outputs for all the zones and the entire network for 3 operating fleet sizes are given in Table 3.10. The results indicate that the number of routes in the optimal solution, the number of transfers saved, the average route length are affected by the size of the operating fleet for the network. Fig. 3.5 shows that as the size of the operating fleet for the network increases, the number of routes in the optimal solution also increases. This happens as increased number of vehicles help in running more routes so as to maximize the number of transfers saved. It is also shown in Fig. 3.6 that the more number of transfers are saved with increased number of routes or increased size of the operating fleet. The simple linear relationships obtained for the

TABLE 3.10 : SUMMARY OF OUTPUTS FOR THE DIFFERENT ZONES AND NETWORK

Sl. No.	Part of Network	Fleet Size	Number of Optimal Routes	Maximum Frequency	Number of Transfers Saved
1	Central	52 69 88	8 14 23	340 340 333	235777 288417 323074
2	West	102 114 117	35 35 35	120 120 120	316841 316841 316841
3	North	154 166 172	34 34 34	111 111 111	334631 334631 334631
4	South-East	99 110 114	35 43 43	224 223 223	354924 358692 358692
5	East	64 72 74	16 30 30	141 123 123	200665 230307 230307
6	North - East	114 125 129	32 32 32	170 170 170	339228 339228 339228
7	South and South-West	85 94 96	26 28 28	192 192 192	269310 270043 270043

FOR NETWORK:

TOTAL FLEET SIZE : 670, 750, 790

TOTAL NO. OF OPTIMAL ROUTES: 160, 191, 207

AVERAGE ROUTE LENGTH (Kms.): 6.625, 6.11, 5.8

TOTAL NO. OF TRANSFERS SAVED (10^3) : 2052, 2138, 2173.

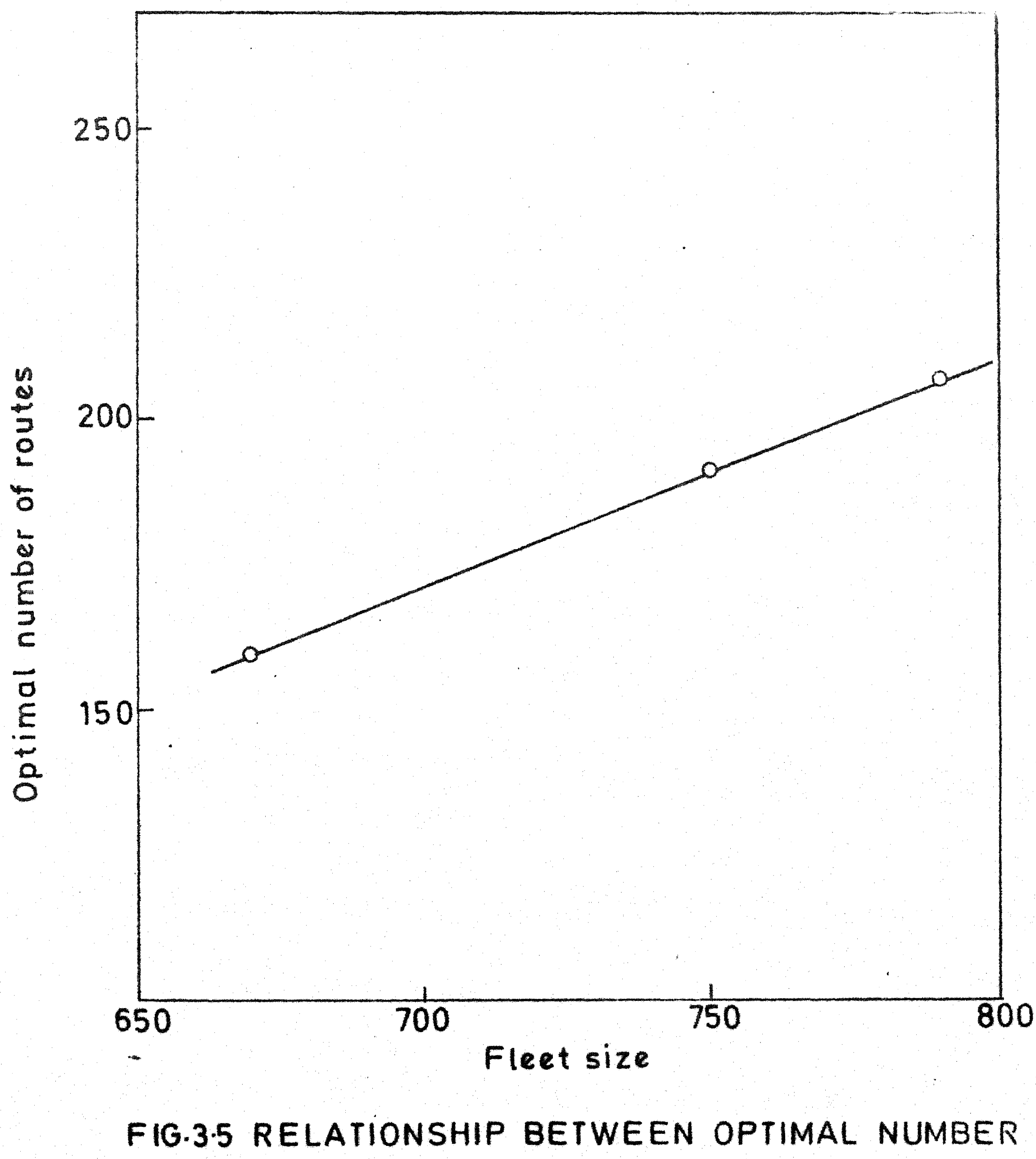


FIG.3.5 RELATIONSHIP BETWEEN OPTIMAL NUMBER OF ROUTES AND FLEET SIZE FOR THE NETWORK.

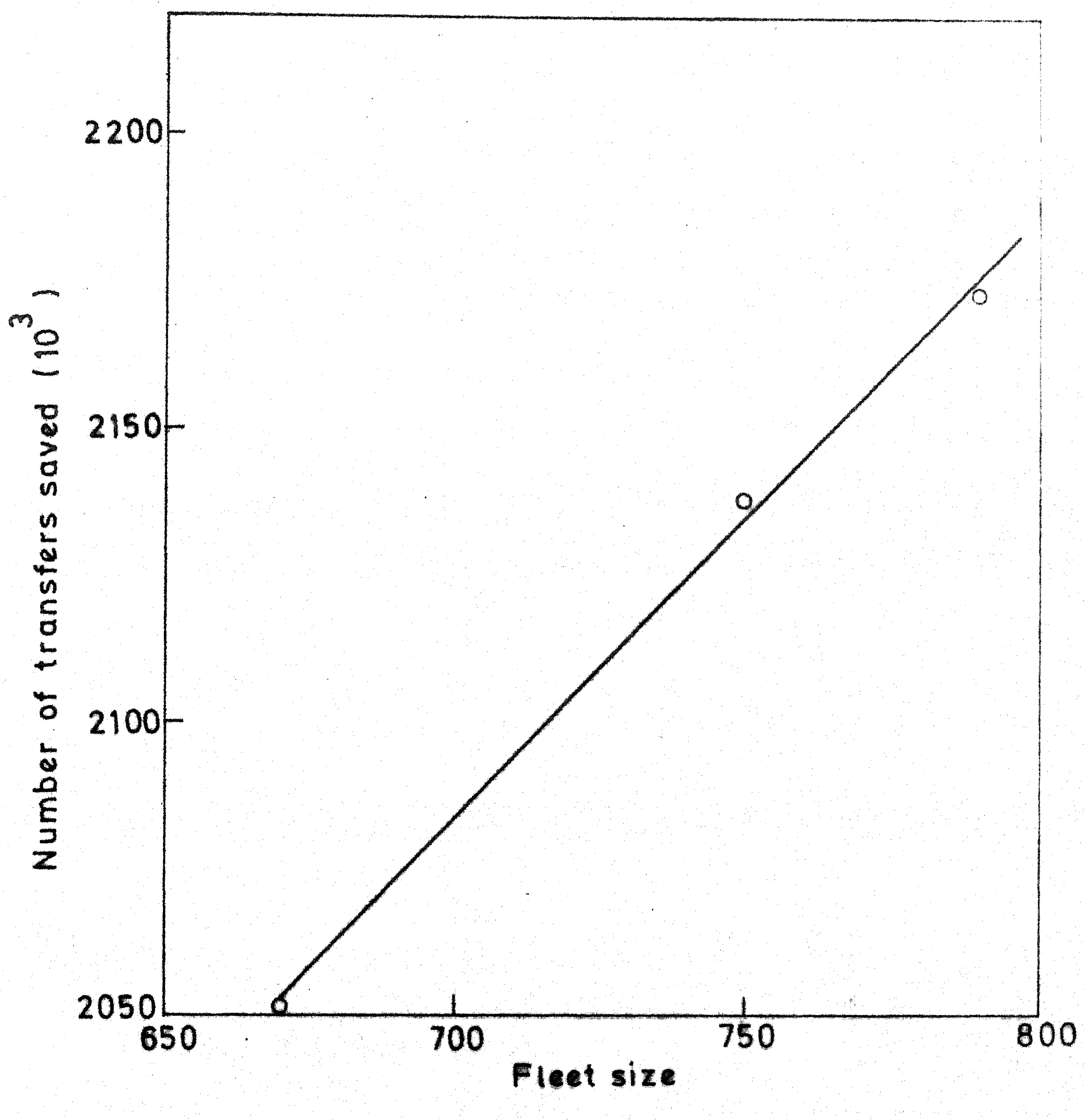


FIG. 3·6 RELATIONSHIP BETWEEN NUMBER OF TRANSFERS SAVED AND FLEET SIZE FOR THE NETWORK.

limited range of the operating fleet size as used in this experiment are

$$Y_1 = -102.0893 + 0.39107(X) \qquad (670 \leq X \leq 790) \tag{3.25}$$

$$Y_2 = 1371179 + 1017.85(X) \qquad (670 \leq X \leq 790) \tag{3.26}$$

where

Y_1 = Number of optimal routes

Y_2 = Number of transfers saved

X = Operating Fleet size.

By increasing the fleet size, the number of routes in optimal solution increases, then the tendency is to have shorter routes. Fig. 3.7 shows that the average length of the route decreases with fleet size and has the following trend:

$$Y_3 = 11.197 - 0.0068125(X) \qquad (670 \leq X \leq 790) \tag{3.27}$$

where

Y_3 = Average length of a route for a network.

X = Operating fleet size.

The frequency distribution of the route lengths for one size of operating fleet is shown in Fig. 3.8. The length of the routes vary between 2.0 to 20.0 Km. with a mean of 6.625 Kms.

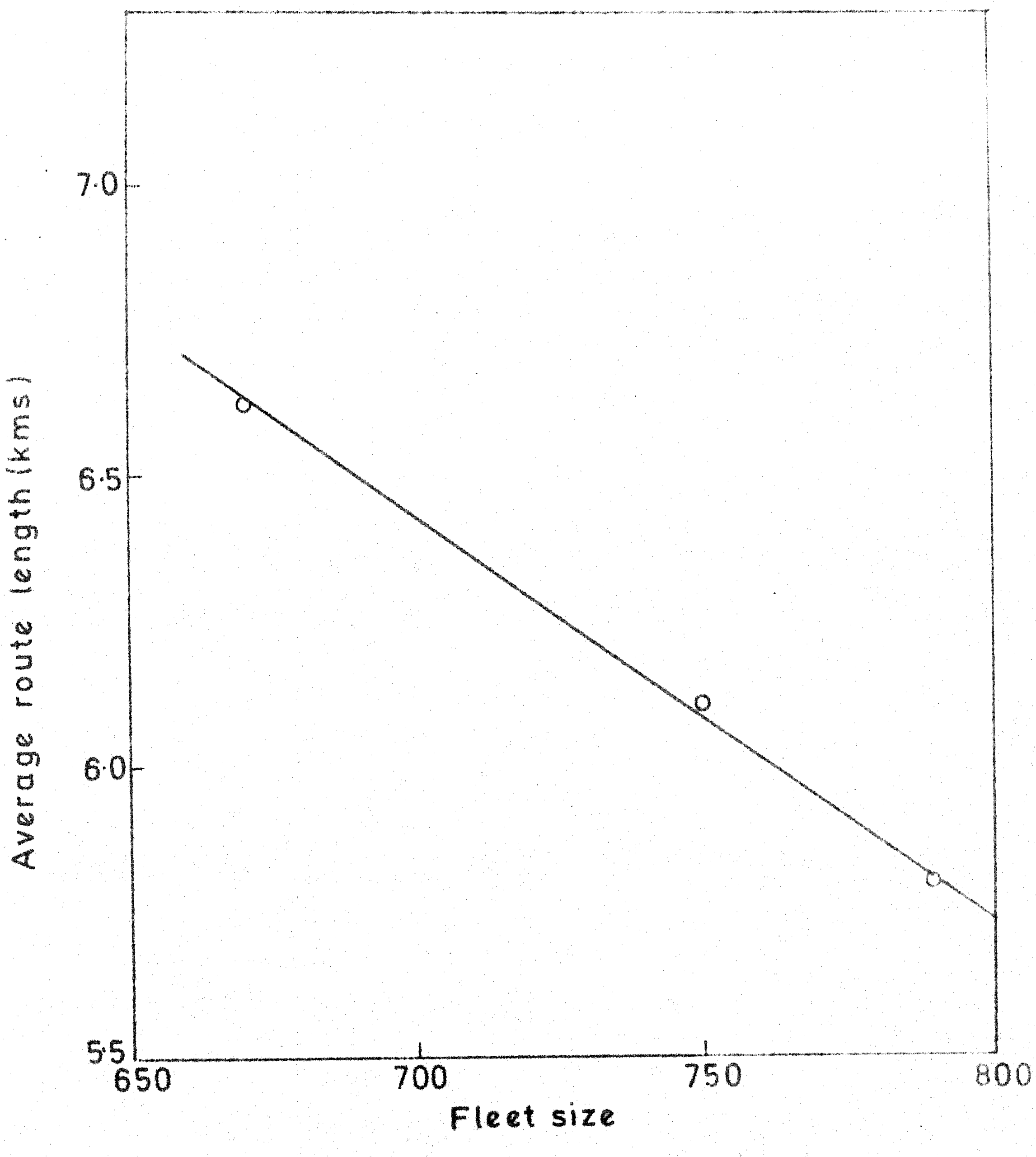


FIG.3·7 RELATIONSHIP BETWEEN THE AVERAGE ROUTE LENGTH AND FLEET SIZE FOR THE NETWORK.

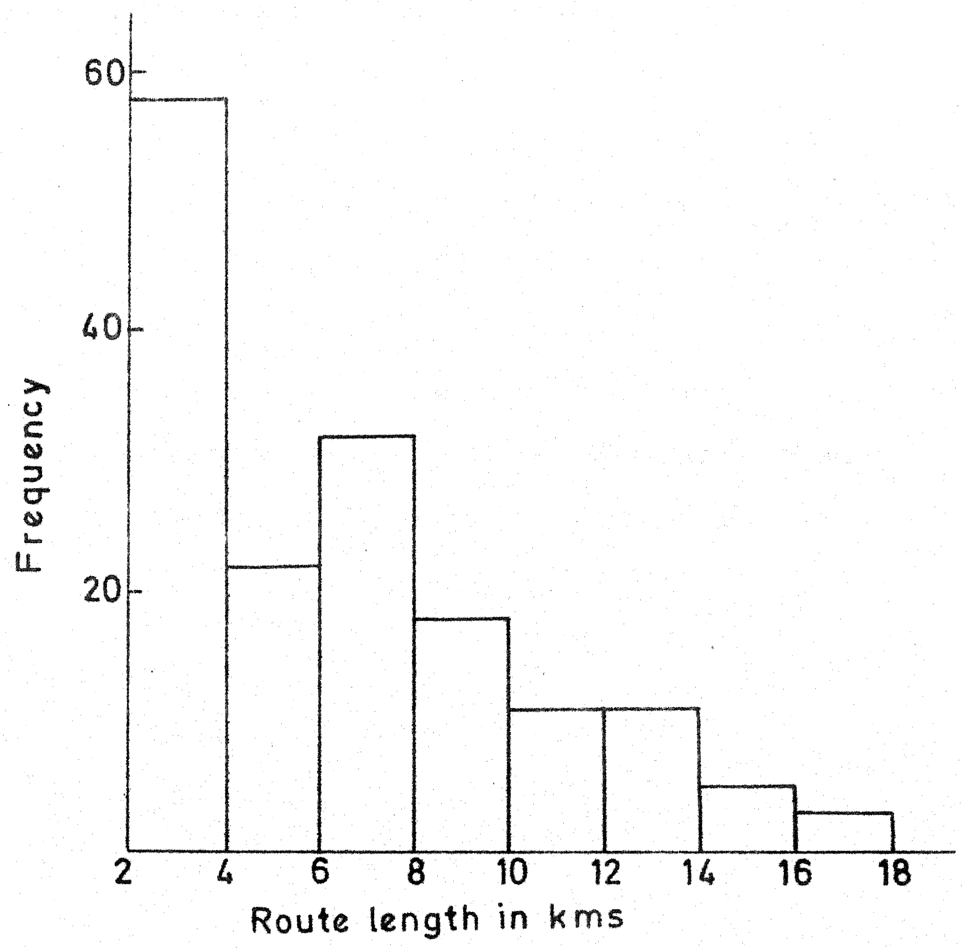


FIG.3·8 FREQUENCY DISTRIBUTION OF ROUTE LENGTHS FOR OPTIMAL ROUTES (FLEET SIZE=670).

Table 3.11 shows the details of relative loading of the terminals. In the existing network, the two major termini namely Lal-darwaja and Kalupur are already saturated. Lal-darwaja has 77 originating routes and Kalupur has 47 originating routes. The facilities at these two terminals are not adequate and suffer from poor accessibility conditions. But the optimal routes obtained from this model lay relatively less emphasis on the utilisation of Lal-darwaja (node 1) and Kalupur (node 4) termini as it can be seen from the table that 51 routes originate from Lal-darwaja and 30 routes originate from Kalupur termini. In all routes originate from 89 stops.

Table 3.10 indicates that the effect of operating fleet size on the routing system for a zone depends upon its size, traffic demand and the land use pattern. The central zone which is quite small in area compared to other zones has been found to be quite sensitive to changes in fleet size compared to other zones. The optimal routes with their paths obtained for the central zone for 3 different fleet sizes are shown in Figs. 3.9 to 3.11. By changing the fleet size from 52 to 88 the number of routes in the optimal solution increase from 8 to 23. Fig. 3.12 shows the relationships for the optimal number of routes and the number of transfers saved with respect to operating

TABLE 3.11: RELATIVE LOADING OF TERMINALS FOR THE OPTIMAL SET OF ROUTES

Sl. No.	NODE	NO. OF ROUTES ORIGIN.	ROUTE NOS.
1	1	51	9 23 24 25 44 45 46 47 48 49 50 57 58 59 60 61 62 66 67 68 69 70 77 78 79 80 81 85 88 94 96 97 103 104 105 106 107 110 112 116 117 119 120 122 124 127 129 145 156 157 158
2	4	30	10 23 26 27 28 51 71 72 73 74 75 80 81 82 83 84 99 114 130 132 134 136 142 143 146 147 149 153 159 160
3	5	1	10
4	7	2	11 29
5	10	9	12 30 52 76 113 115 121 123 137
6	11	5	1 3 31 32 98
7	12	4	4 51 53 63
8	14	1	5
9	15	5	11 29 93 128 133
10	17	15	33 63 71 72 86 87 126 130 131 133 138 148 151 154 155
11	18	2	57 66
12	19	2	31 32
13	21	3	95 123 141
14	22	3	105 106 108
15	24	2	58 109
16	26	1	54
17	32	13	13 14 15 44 45 53 73 74 75 76 92 140 147
18	33	1	152
19	34	1	59
20	36	3	120 121 129
21	3[illegible]	2	134 135
22	41	5	1 12 26 27 33
23	42	2	34 35
24	43	2	16 28
25	44	1	145

Contd.......

TABLE 3.11 (CONTD.)

Sl. No.	ADDF	No. of Routes Origin.	Route Nos.
26	45	5	36 67 68 98 131
27	47	1	159
28	48	2	94 135
29	49	4	116 117 118 136
30	53	4	6 30 111 112
31	55	4	96 97 101 102
32	56	2	16 17
33	57	3	46 47 48
34	58	2	2 17
35	59	1	95
36	60	1	60
37	62	3	2 34 35
38	63	7	36 92 99 100 118 140 144
39	64	1	132
40	65	1	137
41	66	4	18 37 38 64
42	68	5	91 138 141 143 144
43	71	2	93 142
44	72	2	139 146
45	74	1	139
46	75	2	19 20
47	81	2	18 19
48	82	9	64 69 109 111 118 151 152 153 154
49	85	1	157
50	86	6	13 14 21 24 25 55
51	87	2	39 49
52	88	5	83 84 102 108 150
53	91	3	39 55 149
54	93	5	7 20 22 37 50
55	94	2	15 21

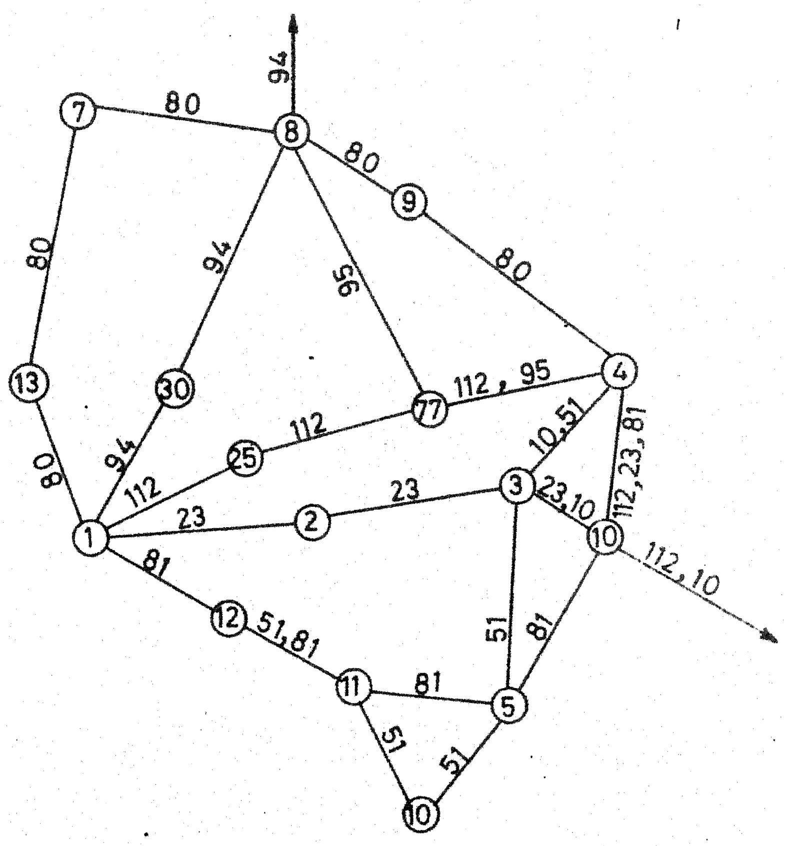
Contd....

122/A

TABLE 3.11 (CONTD.)

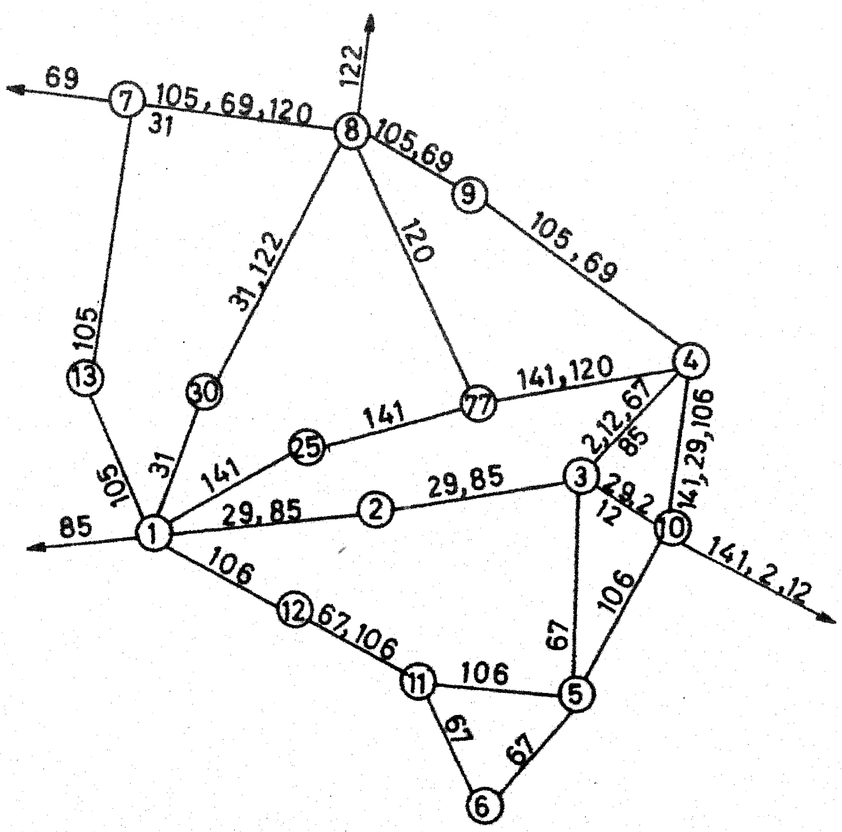
Sl. No.	NODE	NO. OF ROUTES ORIGIN.	ROUTE NOS.						
56	95	2	7	9					
57	99	6	22	40	41	42	61	62	
58	100	1	8						
59	101	3	40	155	156				
60	102	1	159						
61	104	1	160						
62	105	2	41	158					
63	106	2	1	3					
64	108	3	6	107	114				
65	110	7	8	56	70	86	89	90	125
66	111	1	85						
67	112	1	43						
68	114	1	5						
69	117	2	103	126					
70	118	1	104						
71	119	1	43						
72	120	5	42	54	65	77	78		
73	122	4	65	87	91	92			
74	124	2	88	125					
75	125	3	56	89	90				
76	130	2	52	100					
77	133	1	110						
78	134	1	113						
79	135	1	115						
80	136	1	127						
81	137	1	38						
82	139	4	79	119	122	123			
83	140	1	101						
84	141	1	124						

122/1



OPERATING FLEET : 52 NO. OF ROUTES IN OPTIMAL SOLUTION : 8 NO. OF TRANSFERS SAVED : 235777	—(3)— NODE 3 ○ 51 ○ ROUTE NO. 51

FIG. 3.9 ROUTE NETWORK FOR CENTRAL ZONE (OPERATING FLEET=52).



OPERATING FLEET : 69

NO OF ROUTES IN OPTIMAL SOLUTION:14

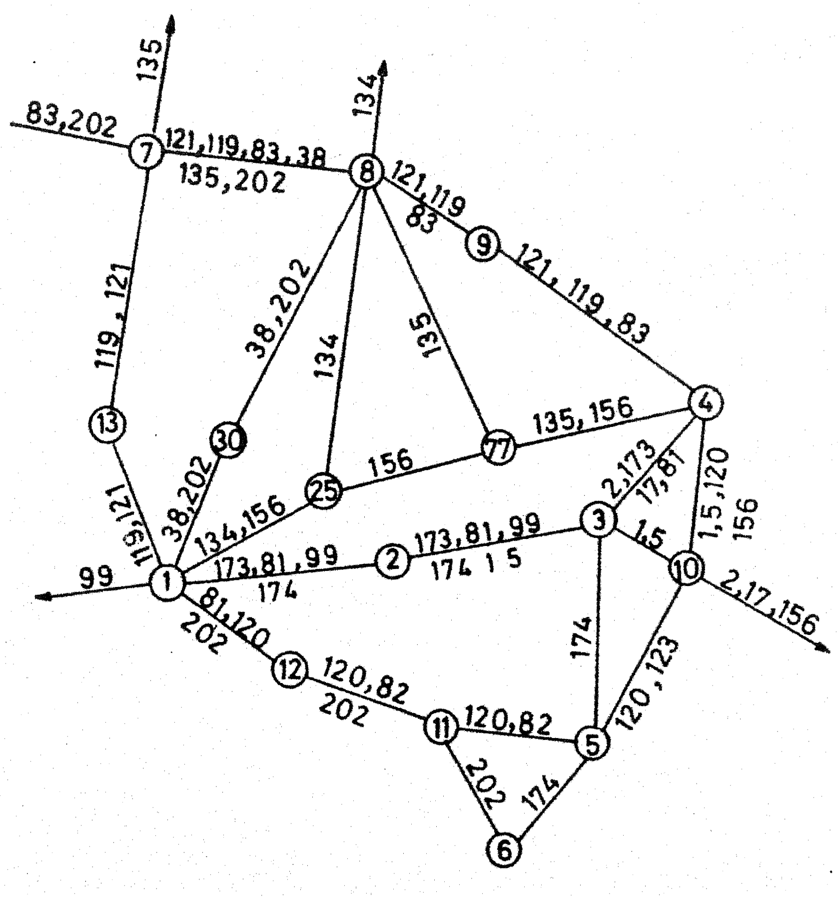
NO OF TRANSFERS SAVED: 288417

NODE 4

12 ROUTE NO 12

NOT TO SCALE

FIG. 3·10 ROUTE NETWORK FOR CENTRAL ZONE (OPERATING FLEET = 69).



OPERATING FLEET : 88

NO OF ROUTES IN OPTIMAL SOLUTION : 23

NO OF TRANSFERS SAVED : 323074

—(4)— NODE 4

○—1—○ ROUTE NO1

FIG-3·11 ROUTE NETWORK FOR CENTRAL ZONE (OPERATING FLEET=88).

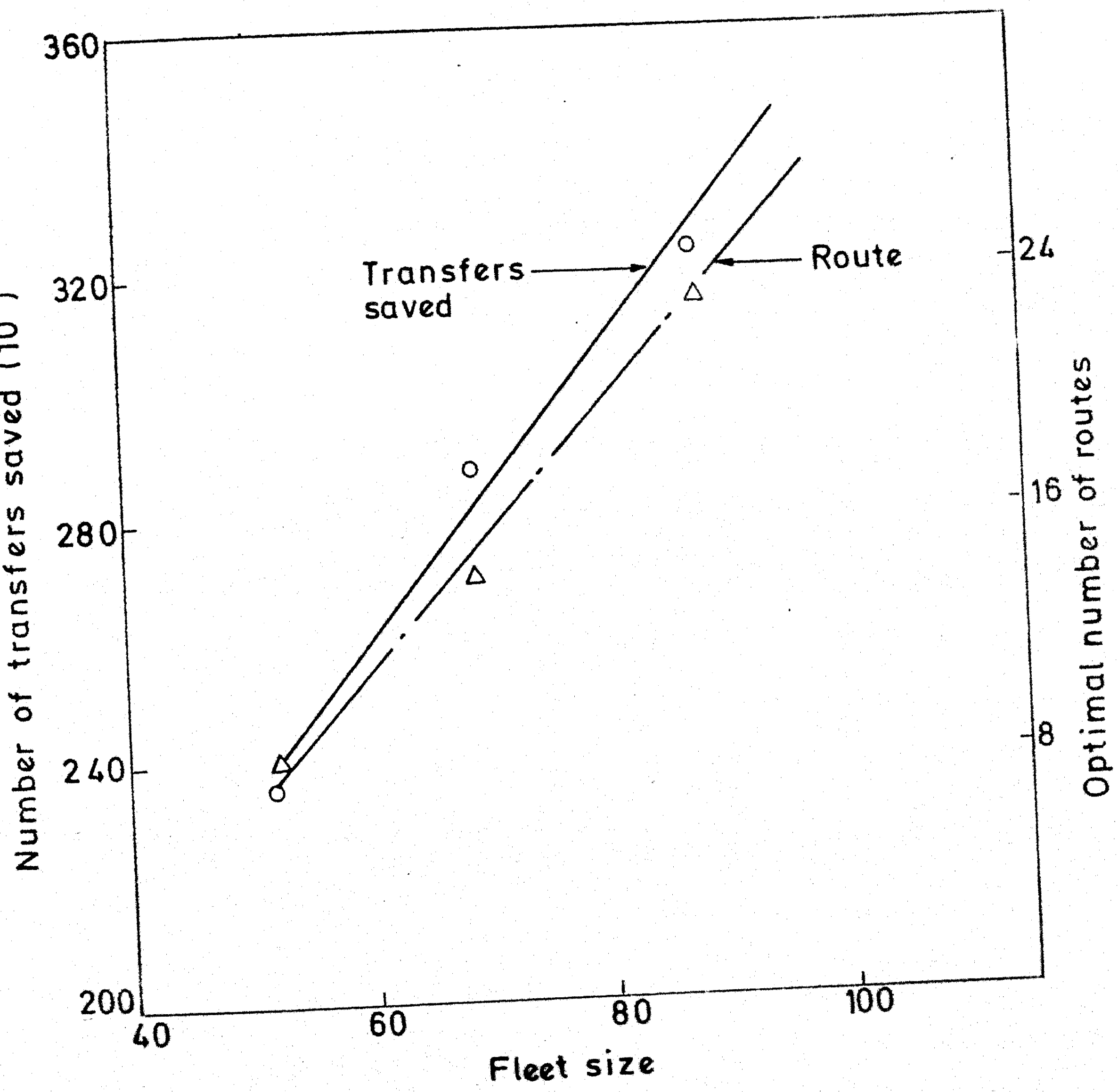


FIG. 3.12 RELATIONSHIPS BETWEEN NUMBER OF TRANSFERS SAVED, OPTIMAL NUMBER OF ROUTES AND FLEET SIZE (Central zone).

fleet size of the central zone. Mathematically, the relations can be expressed as:

$$Y_4 = -14.105 + 0.41778(X) \qquad (3.28)$$

$$(52 \leq X \leq 88)$$

$$Y_5 = 114304.2 + 2413.183(X) \qquad (3.29)$$

$$(52 \leq X \leq 88)$$

where

Y_4 = The optimal number of routes

Y_5 = The number of transfers saved

X = Operating fleet size for the central zone.

The coefficients for the above equations differ from those of the Eqns. 3.25 , 3.26 for the entire network. These coefficients can similarly be obtained for other zones.

The maximum frequency of a route in a zone depends upon the travel demand. Table 3.10 indicates that the maximum frequency is insensitive to the range of the operating fleet sizes considered in this experiment.

4 SUMMARY, CONCLUSIONS AND SUGGESTIONS

4.1 Summary

A few major limitations of the past research in the area of routing and scheduling of the bus transit system are : (i) the generation of routes and scheduling of vehicle in the network is done sequentially, (ii) evaluation of alternative paths of a route is carried out independent of the already accepted routes for the network.

In this study, an attempt has been made to develop a method such that the selection of the routes and the assignment of frequencies is done simultaneously for the bus transit system. The method has been developed in four stages: (i) to generate a trip distribution matrix, (ii) to concentrate the flow of passengers on the road network such that the sum of passenger-riding-time-cost and operation cost is minimized, (iii) to generate a large set of all possible routes that satisfy the various constraints, (iv) to select routes and their frequencies so that number of transfers saved on the network is maximized. Heuristics have been used for the concentration of the flow and generation of the routes while Linear Programming (LP) has been used to select routes and their frequencies.

A method has been suggested to estimate trip distribution matrix by using generally available traffic data of the existing routes for the city bus network.

The flow of passengers on the various links of the network is concentrated such that the sum of passenger-riding-time-cost and operation cost of the vehicles is minimized. An heuristic algorithm has been developed for concentrating the flow. The relationship between the number of bus trips and the flow of passengers on a link has also been derived. The starting network consists of all the links where vehicles could possibly travel. Passenger flows have been systematically concentrated by eliminating the links, in stages such that the total cost is minimized.

For a given desired travel matrix, a large set of all possible routes between different O-D pairs is generated using an heuristic procedure. The generated routes satisfy the practical constraints of length and the deviation from the shortest path.

The total number of transfers saved on a route is determined based on the size of the turning movements along the route and the estimated number of bus trips on the links. For a given operating fleet size, the

simultaneous selection of routes and their frequencies is done by Linear Programming such that the total number of transfers saved on the network is maximized.

Ahmedabad city has been chosen for the case study for structuring of the bus transit network. The optimal set of routes and their frequencies have been estimated for three operating fleet sizes.

4.2 Conclusions

The proposed method is a valuable tool for simultaneous selection of optimal routes and their frequencies for a bus transit network. It can be used by the planner in:

(i) structuring of routes in a rational and systematic way for the given spatial distribution of travel demand;

(ii) finding the number of buses and frequencies on each route and operating fleet size for the system.

Based on the application of the model for the city of Ahmedabad, the following conclusions can also be drawn:

(a) The suggested procedure for the estimation of O-D matrix uses the generally available traffic data of the existing routes in a city bus network. In

cities where trip distribution matrix is not available this method is quite valuable.

(b) The number of bus trips (Y) on a link for a day varies with the passenger flow (X) on the link. The relationship has been established for the city of Ahmedabad and is of the form $Y = aX^b$.

(c) For a given spatial distribution of travel demand, the optimal total cost (passenger-riding-time-cost + operation cost) can be obtained from the algorithm that concentrates the flow on the links.

(d) The method first distributes the passengers on the links in the network and then generates routes that follow the passengers. This method is computationally quite efficient, compared to other methods that repeatedly distribute the passengers on trial networks.

(e) Route generating procedure developed in this study is a systematic and rational algorithm to generate a large set of all possible routes that satisfy the various requirements.

(f) Selection of optimal set of routes and their frequencies is made through an Linear Programming formulation which maximizes the number of transfers saved on the network. This method is more realistic

as the interaction of various routes is taken into consideration.

(g) The application of the model to the city of Ahmedabad indicates that the model can be successfully applied for a large size transit networks and the results are quite encouraging.

(h) The results indicate that the number of routes in the optimal solution, number of transfers saved, increase linearly with increase in operating fleet size. However the average length of the route decreases with the increase in operating fleet size.

4.3 Suggestions for Future Study

Any future work in this direction may include the consideration of the following aspects of the problem:

1. Structuring of routes and the assignment of frequencies is done for a given desired trip matrix. Further refinement of the suggested model may take care of the stochastic variations in the travel demand.
2. The frequencies assigned are for the day. The variations of headways during the day need to be investigated.

3. Operater cost and passenger-riding-time-cost have been considered in terms of time by estimating their weights. The analysis can be made more realistic by considering the actual costs.

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APPENDIX I

STOPS IN AHMEDABAD CITY BUS NETWORK

Code No.	Name of the stop	No. of routes touching the stop
1	2	3
1	Lal Darwaja	98
2	Fuwara	6
3	Khadia Char Rasta	10
4	Kalupur	70
5	Raipur Darwaja	47
6	S.T. Bus Station	24
7	Sharpur Chakla	27
8	Delhi Darwaja	58
9	Dariapur Tower	10
10	Sarangpur	55
11	Astodia Chakla	36
12	Khamasa	43
13	Khanpur	8
14	Municipal Staff Quarters (Dudheshwar)	6
15	Dudheshwar	6
16	Dariakhan Ghummat	2
17	Maninagar	23
18	Jawahar Chowk (Maninagar)	10

Contd....

Appendix I contd...

1	2	3
19	Shah Alam Tol Naka	14
20	Patel Mills	13
21	Bapunagar Terminus	6
22	Bapunagar Char Rasta (Vina Hospital)	9
23	Bombay Housing Colony	8
24	Shardaben Hospital	18
25	Patthar Kuwa	13
26	Income Tax Office	50
27	Sardar Stadium	10
28	Lal Bunglow (Lal College)	8
29	Panchavatti	18
30	Mirzapur Gardens (Jansatta)	23
31	Nutan Society	6
32	Paldi	30
33	Jamalpur Char Rasta	15
34	Pushpa Kunj	16
35	Uttamnagar	4
36	Isanpur	4
38	Daxini Society	4
39	Krishna Baug	15
40	L.G. Corner	10

Contd....

Appendix I contd..

1	2	3
41	Major Dairy	17
42	Idgah Chowky	16
43	Haripura	10
44	Civil Corner	3
45	Civil Hospital	18
46	Dafnala	9
47	Sadar Bazar Camp	6
48	Sardarnagar	4
49	Laxminarayan Society	5
50	Ambica Mills	11
51	New Cottan Mills	5
52	Gomtipur Darwaja	11
53	Rakhial Char Rasta	18
54	Chamunda	18
55	Chamanpura Choktha	10
56	Asarwa Chakla	12
57	Kamdar Maidan	24
58	Girdharnagar	13
59	Circuit House	10
60	Khokhra Mehmadabad	12
61	Amraiwadi	5
62	M.L.A. Quats.	16
63	Meghaninagar	10

Contd.....

Appendix I contd...

1	2	3
64	Chandola Lake	6
65	S.T. Workshop	6
66	Ganghidham Station	47
67	Fatehnagar	12
68	Vasna	11
69	Juhapura	5
70	P.T. College	5
71	Narayannagar	4
72	Ayojannagar	3
73	Sharda Society	5
74	Chamanpura Hous. College	4
75	V.S. Hospital	16
76	Naranghat Rly. X	21
77	Dhana Suthar's Pol	12
78	Rajnagar Society	5
79	Guj. Friends Soce.	8
80	Raikhad Char Rasta	2
81	Sharda Nandir	3
82	Gujarat University	22
83	St Xavier School	5
84	Naranpura Char Rasta	10

Contd.....

Appendix I contd...

1	2	3
85	Ankur Society	6
86	Gujarat College	19
87	Law College	16
88	Politechnique	11
89	Nilima Park	7
90	Commerce College	18
91	Govnt. Quats.(Ambawadi)	9
92	Jodhpur Gam	4
93	Navrangpura	17
94	Nataraj Cinema	14
95	Sanyas Ashram	48
96	Industrial Corner	3
97	Lal Mills	11
98	Gandhi Chotra	3
99	Usmanpura	36
100	Shri Niketan Society	3
101	Naranpura	5
102	Sardar Patel Colony	6
103	St. Joseph H. School	3
104	Memnagar Garnala	5
105	Vijaynagar	5

Contd....

Appendix I contd...

1	2	3
106	Zoo	15
107	Bapunagar Char Rasta	7
108	L.B.Shashtri Stadium	5
109	Govnt.Colony(Lal Mills)	12
110	Vadaj	28
111	Nava Vadaj	4
112	Vora Roza	9
113	Bombay Housing(Vora Roza)	2
114	Advance Mills	19
117	Saijpur	9
118	Krishnanagar	3
119	Thakkar Bapanagar	2
120	Sabarmati Tolnaka	26
121	Broad Gag. Over Br.	20
122	Jawahar Chowk	10
123	Ramnagar	9
124	O.N.G.C.	6
125	Omkareshvar Mahadev	5
130	Ajit Mills	8
132	Kabir Chowk	10
133	Nagavel Hanuman	6

Contd......

Appendix I contd...

1	2	3
134	Ramrajayanagar	3
135	Rabari Colony	3
136	Hatkeshvar Mahadev	6
137	C.N. Vidhalaya	13
138	Ashok Mills	12
139	Ranipur	5
140	Sewage Farm	2
141	Jivraj Park	2
142	Metre Gauge Garnala	1

APPENDIX II : O D MATRIX FOR AHMEDABAD CITY FOR A DAY

NODE	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	1172	1801	13726	4642	2064	2156	6104	578	510	4764	5070	256
2	804	0	266	869	166	48	0	0	0	0	0	58	0
3	1010	204	0	2501	386	67	0	0	0	68	0	96	0
4	11788	933	2033	0	3417	401	3355	6373	1774	14448	481	1293	88
5	1948	26	132	2444	0	2385	6	5	0	2434	1948	847	0
6	2165	89	96	193	681	0	36	66	0	278	124	104	0
7	1201	0	0	2085	5	45	0	1229	204	120	80	61	63
8	3590	0	0	5486	6	106	2892	0	620	261	197	145	7
9	250	0	0	2251	0	0	239	665	0	49	0	0	0
10	249	0	36	14448	3347	604	100	144	23	0	885	928	0
11	2503	0	0	1115	1918	1274	79	154	0	951	0	1095	0
12	3363	20	44	726	1062	618	66	124	0	448	1703	0	0
13	105	0	0	57	0	0	128	7	1	0	0	0	0
14	58	0	0	50	0	0	16	33	3	0	0	0	1
15	1134	0	0	1554	26	16	262	965	157	54	0	0	39
16	553	0	0	213	0	0	107	91	0	0	0	0	28
17	6744	0	49	3616	1718	618	761	1368	6	1435	1423	1181	0
18	123	0	2	14	13	22	14	22	0	19	22	22	0
19	408	0	3	19	52	92	23	44	0	81	88	75	0
20	0	0	0	105	0	0	0	0	0	910	0	0	0
21	188	0	0	2757	59	0	124	31	0	84	59	54	37
22	505	0	0	245	57	0	71	97	13	120	39	44	10
23	7	0	0	250	0	0	6	0	0	1	0	0	1
24	230	0	0	1586	1	0	20	19	1	2	1	1	2
25	877	0	0	1188	0	0	83	244	0	3	0	0	24
26	1527	0	0	1643	2	49	859	1116	175	123	88	66	0
27	55	0	0	23	0	0	10	15	1	0	0	0	0
28	49	0	0	2	0	2	1	1	0	0	5	3	0
29	0	0	0	6	0	0	2	3	0	0	0	0	0
30	3335	0	0	0	3	66	423	1108	241	0	123	89	0
31	42	0	1	18	0	0	0	0	1	0	0	2	0
32	964	49	98	1384	201	72	276	45	15	306	74	369	37
33	397	5	11	284	94	29	0	0	0	178	54	166	0
34	288	0	7	334	132	29	13	29	0	105	68	52	0
35	31	0	1	0	5	5	0	0	0	6	5	5	0
36	1033	0	26	0	107	198	0	0	0	135	232	208	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	579	0	59	1185	475	18	0	0	0	146	115	94	0
39	167	0	7	149	71	11	10	24	0	10	36	27	0
40	23	0	1	176	52	3	0	0	0	74	3	3	0
41	455	0	15	547	393	0	1	2	0	154	72	78	0
42	565	0	0	800	96	0	0	1	26	144	42	59	0
43	53	0	0	101	7	0	0	0	2	22	5	20	0
44	124	0	0	106	0	0	0	0	0	1	0	0	0
45	274	0	0	973	417	0	23	13	13	469	252	28	2
46	321	0	0	29	0	0	0	105	0	1	0	0	0
47	1056	0	0	20	0	0	23	349	0	1	0	0	0
48	715	0	0	2191	33	0	0	210	0	990	0	0	0

Contd......

APPENDIX II (contd.)

NODE	1	2	3	4	5	6	7	8	9	10	11	12	13
49*	790	0	0	395	187	52	0	0	0	237	74	100	0
50*	113	0	0	19	31	2	0	0	0	11	13	18	0
51*	14	0	0	18	2	0	3	7	0	9	2	2	0
52*	32	0	0	249	13	0	0	0	0	295	7	5	0
53*	249	0	0	711	42	0	0	0	0	1249	29	23	0
54*	109	0	0	850	48	0	0	2	0	486	0	0	0
55*	2021	0	0	1722	254	0	13	16	104	425	170	617	0
56*	132	0	0	135	15	0	0	0	5	24	3	0	0
57*	161	0	0	289	54	0	28	48	6	2597	37	31	0
58*	175	0	0	150	16	0	18	11	7	15	5	0	1
59*	80	0	0	92	0	0	11	55	0	0	0	0	1
60*	423	0	0	20	50	41	0	0	0	13	63	71	0
61*	0	0	0	1496	0	1	390	650	97	813	0	0	0
62*	209	0	0	369	27	0	22	11	9	180	9	35	2
63*	2078	0	0	1199	218	0	287	145	72	351	0	0	33
64*	149	0	93	452	201	15	0	0	0	23	7	13	0
65*	14	0	7	37	221	81	0	0	0	288	0	2	0
66*	7021	5	10	852	170	18	41	0	13	9	136	143	6
67*	481	0	0	10	36	0	0	0	0	46	24	29	0
68*	2054	0	0	877	653	59	0	0	0	266	302	347	0
69*	1823	0	0	0	371	0	0	0	0	620	296	345	0
70*	339	1	2	31	0	0	3	0	0	1	0	0	0
71*	1189	55	113	1127	48	0	102	0	0	97	32	52	0
72*	939	22	45	396	0	0	0	0	70	0	0	130	0
73*	37	0	0	13	0	0	0	0	0	0	0	1	0
74*	925	0	0	0	0	0	41	70	70	0	0	0	0
75*	637	0	0	57	24	0	15	0	6	3	13	15	2
76*	287	0	0	227	0	0	33	165	16	0	0	0	2
77*	729	0	0	2900	0	0	88	26	0	3	0	0	19
78*	35	2	5	48	0	0	1	0	0	1	0	0	0
79*	167	0	0	24	0	0	7	13	0	0	0	0	0
80*	3	1	3	32	0	1	0	0	0	0	0	0	0
81*	296	0	0	20	2	2	0	0	0	7	0	0	0
82*	2421	1	2	642	119	222	41	58	3	0	383	360	0
83*	7	0	0	5	0	0	2	3	0	0	0	0	0
84*	110	0	0	53	0	5	27	46	7	0	7	7	0
85*	1457	0	0	785	0	0	306	500	106	0	0	0	0
86*	622	1	2	94	15	6	0	0	0	0	23	22	0
87*	165	0	0	9	5	7	0	0	0	0	15	13	0
88*	660	0	0	2004	286	141	378	531	57	499	89	65	0
89*	31	0	0	55	0	0	7	11	0	0	0	0	0
90*	206	1	2	145	5	0	31	48	3	0	3	3	0
91*	302	0	0	109	0	0	0	0	0	0	0	0	0
92*	681	0	0	0	0	0	0	0	0	0	0	0	0
93*	214	0	1	127	3	0	29	42	2	0	3	2	0
94*	257	0	0	0	0	0	10	0	0	0	0	0	0
95*	1349	0	0	44	0	0	23	0	0	0	0	0	0
96*	31	0	0	31	0	0	0	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	1	2	3	4	5	6	7	8	9	10	11	12	13
97	0	0	0	6	0	0	0	0	0	3	0	0	0
98	466	19	40	518	0	0	0	0	0	0	0	0	0
99	625	0	0	479	1	22	208	340	52	50	41	31	0
100	405	0	0	244	0	7	74	124	32	0	9	10	0
101	1713	0	0	746	0	224	551	919	101	0	275	300	0
102	492	0	0	370	0	0	188	218	50	0	0	0	0
103	5	0	0	18	1	0	3	7	0	9	1	1	0
104	1163	0	0	189	0	0	152	223	22	0	0	0	0
105	955	0	0	348	0	0	239	351	46	0	0	0	0
106	27	0	0	0	0	2	0	0	0	0	1	3	0
107	2	0	0	141	0	0	3	0	0	1	0	0	1
108	2204	0	0	2702	0	0	0	0	0	950	0	0	0
109	0	0	0	0	0	0	0	0	0	759	0	0	0
110	1687	0	0	1961	1	206	863	1571	145	902	518	260	0
111	1355	0	0	835	0	0	392	735	114	0	0	0	0
112	0	0	0	171	0	0	0	0	0	0	0	0	0
113	0	0	0	61	0	0	0	0	0	0	0	0	0
114	162	0	0	105	0	0	9	101	11	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0	0	0	0	0
117	2022	0	0	6692	789	0	0	37	13	3242	0	0	0
118	42	0	0	1413	9	0	0	0	0	859	6	6	0
119	0	0	0	3411	0	0	0	0	0	0	0	0	0
120	163	0	0	205	1	0	27	102	22	0	1	1	0
121	98	0	0	270	1	0	53	118	32	0	0	1	0
122	1084	0	0	607	41	0	210	529	78	0	39	41	0
123	10	0	0	28	0	0	44	81	2	0	0	0	0
124	534	0	0	1193	0	0	157	465	162	0	0	0	0
125	1049	0	0	318	0	0	52	235	42	0	0	0	0
126	0	0	0	0	0	0	0	0	0	0	0	0	0
127	0	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	0	0	0	0	0	0	0	0
130	16	0	0	46	7	0	0	0	0	4035	3	2	0
131	0	0	0	0	0	0	0	0	0	0	0	0	0
132	0	0	0	75	0	0	0	37	13	0	0	0	0
133	644	0	0	0	332	0	0	0	0	0	222	144	0
134	162	0	0	0	49	0	0	0	0	382	32	32	0
135	357	0	0	0	88	37	0	0	0	513	83	88	0
136	2453	0	0	267	769	1	0	0	0	153	401	435	0
137	453	0	0	79	15	7	0	0	0	32	3	2	0
138	66	0	0	816	42	0	0	0	0	569	0	0	0
139	3038	0	0	0	171	326	0	0	0	287	283	378	0
140	230	0	0	829	254	0	0	0	0	425	170	664	0
141	1207	0	0	559	0	0	0	0	0	0	0	0	0
142	401	0	0	0	0	0	106	133	0	0	0	0	0
TOTAL	108371	2606	5013	112102	25331	10327	17473	29590	5444	46880	16821	17193	662

APPENDIX II (contd.)

NODE	14	15	16	17	18	19	20	21	22	23	24	25	26
1*	313	361	96	1656	594	1383	0	3	67	6	799	1588	3759
2*	0	0	0	0	0	0	0	0	0	0	0	0	0
3*	0	0	0	45	3	6	0	0	0	0	0	0	0
4*	205	253	14	1426	42	55	335	647	331	1216	7644	555	3604
5*	0	0	0	2041	61	145	0	2	13	5	10	0	2
6*	0	0	0	1297	621	1475	0	0	0	0	0	0	48
7*	611	707	111	65	22	32	0	3	5	7	20	9	4095
8*	1281	1508	10	156	46	75	0	1	13	1	24	27	3615
9*	28	37	0	0	0	0	0	0	0	0	1	0	280
10*	2	2	0	751	83	241	2048	7	215	11	23	2	115
11*	0	0	0	1401	405	1028	0	2	5	3	7	0	105
12*	0	0	0	718	245	496	0	1	5	2	5	0	89
13*	79	107	42	0	0	0	0	1	0	2	3	2	0
14*	0	2466	165	0	0	0	0	0	0	0	1	3	2
15*	154	0	639	22	16	15	0	18	0	37	57	158	117
16*	32	36	0	0	0	0	0	0	0	0	0	0	0
17*	6	6	0	0	217	461	59	0	0	140	304	0	978
18*	0	0	0	2160	0	19	0	0	0	0	0	0	18
19*	0	0	0	1480	1042	0	0	0	0	0	0	0	29
20*	0	0	0	36	0	0	0	0	260	2	7	0	0
21*	18	28	0	0	0	0	0	0	0	270	529	46	0
22*	0	0	0	0	0	0	2	0	0	0	29	0	29
23*	0	1	0	49	0	0	5	1058	0	0	98	2	0
24*	1	2	0	92	0	0	11	609	349	1292	0	19	18
25*	57	53	0	0	0	0	0	1	0	3	59	0	0
26*	16	22	0	71	22	33	0	0	1	0	3	0	0
27*	0	0	0	0	0	0	0	0	0	0	0	0	18
28*	0	0	0	2	0	0	0	0	0	0	0	0	1
29*	0	0	0	0	0	0	0	0	0	0	0	0	3
30*	0	0	0	96	28	46	0	0	0	0	0	0	560
31*	0	0	0	2	0	2	0	0	0	0	0	0	0
32*	20	14	11	36	0	28	0	0	0	1	2	9	104
33*	0	0	0	14	0	20	0	0	0	0	0	0	0
34*	0	0	0	4574	477	31	0	0	0	0	0	0	19
35*	0	0	0	0	2	6	0	0	0	0	0	0	0
36*	0	0	0	0	139	208	0	0	0	0	0	0	0
37*	0	0	0	0	0	0	0	0	0	0	0	0	0
38*	0	0	0	431	24	36	0	0	0	0	0	0	0
39*	0	0	0	6623	0	13	3	0	0	5	11	0	15
40*	0	0	0	3360	0	6	2	0	0	3	7	0	0
41*	0	0	0	2072	0	0	0	0	0	0	0	0	1
42*	0	0	0	2	0	0	0	0	0	0	0	3	1
43*	0	0	0	0	0	0	0	0	0	0	0	1	0
44*	0	0	0	0	0	0	0	0	0	0	0	15	0
45*	1	0	0	137	0	0	5	0	0	53	96	1	13
46*	0	0	0	0	0	0	0	0	0	0	0	0	0
47*	0	0	0	0	0	0	0	0	0	0	0	0	40
48*	0	0	0	33	0	0	0	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	14	15	16	17	18	19	20	21	22	23	24	25	26
49	0	0	0	35	19	42	0	0	0	0	0	0	0
50	0	0	0	176	0	0	3	0	0	6	13	0	0
51	0	0	0	92	0	0	0	0	0	5	13	0	5
52	0	0	0	55	0	0	0	0	0	7	14	0	0
53	0	0	0	209	0	0	230	0	842	39	183	11	0
54	0	0	0	48	0	0	0	0	0	0	0	7	0
55	0	0	0	36	0	0	5	0	0	10	23	0	24
56	0	0	0	42	0	0	7	0	0	13	29	0	0
57	0	0	0	104	0	0	923	0	163	3	10	0	39
58	0	0	0	5	0	0	2	0	0	1	3	0	9
59	0	0	0	96	0	0	57	3	0	35	81	0	1
60	0	0	0	388	0	1	0	0	0	7	19	0	0
61	0	0	0	70	0	0	0	0	0	2	6	0	520
62	1	0	0	20	0	0	0	0	0	5	14	1	10
63	16	10	10	188	0	0	5	0	0	49	124	57	140
64	0	0	0	0	0	11	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0
66	2	1	1	117	9	15	0	0	0	1	2	443	338
67	0	0	0	3	0	0	0	0	0	0	0	0	7
68	0	0	0	222	0	0	0	9	0	14	29	58	163
69	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	3
71	11	15	0	0	0	0	0	0	0	0	0	0	115
72	0	0	0	0	0	0	0	0	0	0	0	0	0
73	0	0	0	2	0	2	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	0	0	0	62
75	1	0	0	10	0	0	0	0	0	0	1	6	0
76	1	0	0	10	0	0	5	0	0	2	7	0	23
77	10	16	1	0	0	0	0	2	0	5	88	85	0
78	0	0	0	0	0	0	0	0	0	0	0	0	1
79	0	0	0	2	0	2	0	0	0	0	0	0	13
80	0	0	0	1	0	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0	0	0	0	0	0
82	0	0	0	326	44	195	0	0	0	0	5	39	62
83	0	0	0	0	0	0	0	0	0	0	0	0	3
84	0	0	0	7	3	3	0	0	0	0	0	0	44
85	0	0	0	0	0	0	0	0	0	0	0	0	594
86	0	0	0	20	1	5	0	0	0	0	0	42	0
87	0	0	0	11	1	5	0	0	0	0	0	11	0
88	0	0	0	101	0	3	0	0	3	0	7	0	551
89	0	0	0	0	0	0	0	0	0	0	0	0	11
90	0	0	0	5	0	0	0	0	0	0	0	1	49
91	0	0	0	0	0	0	0	0	0	0	0	136	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0
93	0	0	0	3	0	0	0	0	0	0	0	1	44
94	1	1	0	0	0	0	0	0	0	0	0	0	267
95	2	2	0	0	0	0	0	0	0	0	0	7	451
96	0	0	0	0	0	0	0	0	52	0	7	1	0

APPENDIX II (contd.)

NODE	14	15	16	17	18	19	20	21	22	23	24	25	26
97	0	0	0	0	0	0	0	0	0	0	0	0	0
98	0	0	0	0	0	0	0	0	0	0	0	0	0
99	0	0	0	32	11	15	0	0	0	0	0	0	364
100	0	0	0	10	5	5	0	0	0	0	0	0	171
101	0	0	0	300	175	149	0	0	0	0	0	0	734
102	0	0	0	0	0	0	0	0	0	0	0	0	299
103	0	0	0	0	0	0	0	0	0	0	0	0	6
104	0	0	0	0	0	0	0	0	0	0	0	0	197
105	0	0	0	0	0	0	0	0	0	0	0	0	395
106	0	0	0	0	0	0	0	0	0	0	0	0	0
107	0	0	0	23	0	0	0	2293	0	15	39	1	0
108	0	0	0	26	0	0	189	0	53	5	406	163	0
109	0	0	0	33	0	0	0	0	0	7	15	0	0
110	0	0	0	312	0	154	0	0	0	0	0	0	1219
111	0	0	0	0	0	0	0	0	0	0	0	0	552
112	0	0	0	42	0	0	6	0	0	11	65	0	0
113	0	0	0	0	0	0	0	0	0	0	11	0	0
114	0	0	0	0	0	0	0	0	0	0	0	0	15
115	0	0	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0	0	0	0	0
117	0	0	0	789	0	0	0	0	0	0	0	148	0
118	0	0	0	0	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	0	0	54	712	0	0
120	0	0	0	0	0	0	0	0	0	0	0	0	79
121	0	0	0	0	0	0	0	0	0	0	0	0	97
122	0	0	0	31	0	0	0	0	0	0	0	0	510
123	0	0	0	0	0	0	0	0	0	0	0	0	67
124	0	0	0	0	0	0	0	0	0	0	0	0	321
125	0	0	0	0	0	0	0	0	0	0	0	0	221
126	0	0	0	0	0	0	0	0	0	0	0	0	0
127	0	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	0	0	0	0	0	0	0	0
130	0	0	0	0	0	0	807	0	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0	0	0	0	0
132	0	0	0	0	0	0	0	0	0	0	0	0	0
133	0	0	0	0	0	0	0	0	0	0	0	0	0
134	0	0	0	0	0	0	75	0	0	0	0	0	0
135	0	0	0	0	0	18	0	0	0	0	0	0	0
136	0	0	0	0	0	0	0	0	0	0	0	0	0
137	0	0	0	3	0	0	0	0	0	0	0	10	0
138	0	0	0	42	0	0	0	0	0	0	0	3	0
139	0	0	0	0	0	302	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0	0	0	0	0
141	0	0	0	0	0	0	0	0	0	0	0	66	0
142	0	0	0	0	0	0	0	0	0	0	0	0	106
TOTAL	2869	5658	1100	34895	4357	6787	4784	4660	2377	3355	11665	3737	26580

APPENDIX II (contd.)

NODE	27	28	29	30	31	32	33	34	35	36	37	38	39
1	198	230	0	4448	185	3331	1059	925	119	91	0	28	583
2	0	0	0	0	2	48	23	0	0	0	0	0	0
3	0	0	0	0	5	79	39	16	2	2	0	3	20
4	98	10	24	0	69	1696	702	652	0	0	0	87	416
5	0	0	0	2	0	443	271	1168	16	16	0	57	681
6	0	3	0	31	0	322	123	514	78	65	0	10	271
7	127	3	9	166	2	135	0	18	0	0	0	0	16
8	76	2	6	552	1	11	0	50	0	0	0	0	45
9	6	0	0	42	2	14	0	0	0	0	0	0	0
10	0	0	0	0	0	704	469	408	28	28	0	9	35
11	0	9	0	72	0	145	176	715	54	40	0	18	494
12	0	11	0	59	28	783	2714	328	28	20	0	10	219
13	0	0	0	0	0	31	0	0	0	0	0	0	0
14	0	0	0	0	0	5	0	0	0	0	0	0	0
15	0	0	0	0	0	67	0	0	0	0	0	0	0
16	0	0	0	0	0	1	0	0	0	0	0	0	0
17	0	62	0	656	16	358	39	1086	0	0	0	3441	746
18	0	0	0	10	0	0	0	6	665	514	0	371	0
19	0	0	0	19	3	28	13	702	167	136	0	55	306
20	0	0	0	0	0	0	0	0	0	0	0	0	22
21	0	0	0	0	0	79	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	13
24	0	0	0	0	0	2	0	0	0	0	0	0	24
25	0	0	0	0	1	22	0	0	0	0	0	0	0
26	954	10	23	174	7	198	0	20	0	0	0	0	18
27	0	1	5	2	1	9	0	0	0	0	0	0	0
28	57	0	9	0	2	15	0	0	0	0	0	0	0
29	0	0	0	0	13	218	0	0	0	0	0	0	0
30	9	0	0	0	13	63	0	29	0	0	0	0	27
31	0	0	0	6	0	54	2	1	0	0	0	0	1
32	6	9	94	40	1495	0	228	35	0	0	0	0	20
33	0	9	0	0	28	1186	0	18	0	0	0	0	7
34	0	1	0	13	1	29	9	0	218	162	0	88	1617
35	0	0	0	0	0	0	0	2	0	1380	0	0	0
36	0	0	0	0	0	0	0	120	83	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	14	0	0	0	0	0	223	0	0	0	0	200
39	0	0	0	10	1	16	3	33	0	0	0	161	0
40	0	0	0	0	1	7	2	26	0	0	0	16	250
41	0	0	0	1	0	14	1	1171	0	0	0	59	692
42	0	0	0	102	5	29	11	0	0	0	0	0	1
43	0	0	0	11	2	16	3	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	54	5	36	5	0	0	0	0	0	81
46	0	0	0	46	0	0	0	0	0	0	0	0	0
47	0	0	0	169	0	0	0	0	0	0	0	0	0
48	0	0	0	105	0	0	0	0	0	0	0	5	19

APPENDIX II (contd.)

NODE	27	28	29	30	31	32	33	34	35	36	37	38	39
49	0	0	0	0	0	0	19	40	0	0	0	0	20
50	0	0	0	0	0	2	1	0	0	0	0	0	106
51	0	0	0	0	0	0	0	0	0	0	0	0	22
52	0	0	0	0	0	0	0	0	0	0	0	0	33
53	0	0	0	0	0	0	0	0	0	0	0	0	46
54	0	0	0	0	0	0	0	27	0	0	0	0	0
55	0	0	0	366	0	0	127	0	0	0	0	0	11
56	0	0	0	23	0	0	0	0	0	0	0	0	14
57	0	0	0	0	0	0	0	0	0	0	0	0	62
58	0	0	0	31	0	5	0	0	0	0	0	0	2
59	0	0	0	10	0	3	0	0	0	0	0	0	57
60	0	0	0	0	0	5	3	1	0	0	0	0	0
61	0	0	0	0	0	1	0	0	0	0	0	0	0
62	0	0	0	41	3	33	6	0	0	0	0	0	0
63	0	0	0	293	0	201	0	0	0	0	0	0	0
64	0	0	0	0	0	0	14	0	0	0	0	0	0
65	0	0	0	0	0	0	1	0	0	0	0	0	0
66	79	175	0	52	162	3281	5	76	0	0	0	3	61
67	0	0	18	0	0	145	13	2	0	0	0	0	2
68	0	0	219	0	0	994	52	156	0	0	0	0	133
69	0	0	0	0	0	686	197	0	0	0	0	0	0
70	0	0	0	0	0	78	0	0	0	0	0	0	0
71	0	0	0	0	0	309	19	0	0	0	0	0	0
72	0	0	0	284	92	440	53	0	0	0	0	0	0
73	0	0	0	3	0	14	1	1	0	0	0	0	1
74	0	0	0	284	70	331	0	0	0	0	0	0	0
75	0	0	0	27	183	3276	0	7	0	0	0	0	6
76	0	0	0	41	0	7	0	0	0	0	0	0	5
77	0	0	0	0	1	18	0	0	0	0	0	0	0
78	0	0	0	0	0	7	0	0	0	0	0	0	0
79	1	0	0	0	0	3	1	1	0	0	0	0	1
80	0	0	0	0	0	0	0	0	0	0	0	0	1
81	0	0	22	0	0	58	2	0	0	0	0	0	0
82	3	87	85	0	16	243	92	219	0	0	0	7	133
83	0	0	10	1	0	10	0	0	0	0	0	0	0
84	2	0	13	10	0	13	0	0	0	0	0	0	0
85	20	15	209	92	0	209	0	0	0	0	0	0	0
86	72	179	0	0	0	0	0	13	0	0	0	1	9
87	0	231	0	0	0	0	0	5	0	0	0	0	3
88	0	0	0	0	0	361	144	67	0	0	0	15	58
89	0	0	0	0	0	0	0	0	0	0	0	0	0
90	2	0	0	0	0	0	0	2	0	0	0	0	2
91	0	0	0	0	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0
93	122	0	0	0	0	0	0	2	0	0	0	0	2
94	74	0	0	0	0	61	0	0	0	0	0	0	0
95	58	0	0	0	23	999	0	0	0	0	0	0	0
95	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	27	28	29	30	31	32	33	34	35	36	37	38	39
97	0	0	0	0	0	0	0	0	0	0	0	0	0
98	0	0	0	0	0	0	0	0	0	0	0	0	0
99	2	0	0	66	0	31	0	7	0	0	0	0	6
100	0	0	0	14	0	0	0	0	0	0	0	0	0
101	20	15	0	300	0	0	0	0	0	0	0	0	0
102	80	0	0	35	0	0	0	0	0	0	0	0	0
103	0	0	0	0	0	0	0	0	0	0	0	0	0
104	45	0	0	57	0	0	0	0	0	0	0	0	0
105	0	0	0	102	0	0	0	0	0	0	0	0	0
106	0	0	0	0	0	0	1	0	0	0	0	0	0
107	0	0	0	0	0	0	0	0	0	0	0	0	0
108	0	0	0	0	0	0	0	0	0	0	0	0	0
109	0	0	0	0	0	0	0	0	0	0	0	0	19
110	2	0	0	349	0	32	0	206	0	0	0	0	180
111	0	0	0	196	0	0	0	0	0	0	0	0	0
112	0	0	0	0	0	0	0	0	0	0	0	0	13
113	0	0	0	0	0	0	0	0	0	0	0	0	0
114	0	0	0	22	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0	0	0	0	0
117	0	0	0	0	0	0	0	460	0	0	0	0	0
118	0	0	0	0	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	0	0	0	0	0	0
120	2	0	0	6	0	16	0	0	0	0	0	0	0
121	1	0	0	3	0	11	0	0	0	0	0	0	0
122	0	0	0	118	0	143	0	22	0	0	0	0	22
123	0	0	0	0	0	0	0	0	0	0	0	0	0
124	16	0	0	0	0	0	0	0	0	0	0	0	0
125	0	0	0	52	0	0	0	0	0	0	0	0	0
126	0	0	0	0	0	0	0	0	0	0	0	0	0
127	0	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	0	0	0	0	0	0	0	0
130	0	0	0	0	0	0	0	0	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0	0	0	0	0
132	0	0	0	0	0	0	0	0	0	0	0	0	0
133	0	0	0	0	0	0	0	0	0	0	0	0	0
134	0	0	0	0	0	0	0	0	0	0	0	0	0
135	0	0	0	0	0	63	31	24	0	0	0	0	0
136	0	0	0	0	0	1	0	0	0	0	0	0	0
137	16	0	0	0	0	23	7	2	0	0	0	0	2
138	0	0	0	0	0	0	0	24	0	0	0	0	0
139	0	0	0	0	0	0	244	0	0	0	0	0	0
140	0	0	0	0	0	0	162	0	0	0	0	0	0
141	0	0	0	0	45	280	0	0	0	0	0	0	0
142	0	0	0	106	0	0	0	0	0	0	0	0	0
TOTAL	2148	1076	746	9774	2494	22588	7087	9630	1458	2454	0	4444	7856

APPENDIX II (contd.)

NODE	40	41	42	43	44	45	46	47	48	49	50	51	52
1	111	1264	1472	167	26	869	140	159	41	71	387	57	119
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	3	27	0	0	0	0	0	0	0	0	0	0	0
4	354	951	3058	531	94	1151	133	102	349	24	50	131	104
5	422	2346	118	16	0	53	1	1	0	109	582	83	126
6	67	0	0	0	0	0	0	0	0	9	52	0	0
7	0	1	3	0	0	76	0	2	0	0	0	9	0
8	1	3	13	0	0	81	118	145	28	0	0	20	0
9	0	0	247	37	0	148	0	0	0	0	0	3	0
10	313	574	280	52	3	132	6	5	119	31	80	369	660
11	57	488	252	7	0	150	0	0	0	13	128	29	35
12	35	351	58	23	0	35	0	0	0	11	88	16	15
13	0	0	0	0	0	3	0	0	0	0	0	0	0
14	0	0	0	0	0	6	0	0	0	0	0	0	0
15	0	0	0	0	0	3	0	0	0	0	0	0	0
16	0	0	0	0	0	5	0	0	0	0	0	0	0
17	560	916	1	0	0	175	0	0	0	227	115	81	79
18	0	0	0	0	0	0	0	0	0	252	0	0	0
19	78	0	0	0	0	0	0	0	0	15	5	0	0
20	14	0	0	0	0	7	0	0	0	0	18	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	31	0	0	0	0	10	9	7
24	15	0	0	0	0	84	0	0	0	0	19	16	13
25	0	0	19	7	2	10	0	0	0	0	0	0	0
26	0	1	3	0	0	27	0	2	0	0	0	9	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	1	612	101	0	382	26	33	7	0	0	0	0
31	1	0	2	1	0	3	0	0	0	0	0	0	0
32	14	11	26	15	0	79	0	0	0	0	3	0	0
33	18	13	9	2	0	5	0	0	0	5	2	0	0
34	809	70	0	0	0	0	0	0	0	37	13	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	45	275	27	10	7	0	13	10	7	0	0	0	0
39	120	37	1	0	0	13	0	0	0	9	7	2	6
40	0	29	1	0	0	9	0	0	0	31	5	2	5
41	458	0	9	0	0	0	0	0	0	120	716	0	0
42	1	11	0	516	102	1647	62	48	33	1	5	0	2
43	0	0	24	0	105	586	40	31	22	0	0	0	1
44	0	0	20	7	0	0	28	23	16	0	0	0	0
45	54	0	278	13	0	0	0	0	0	0	67	37	79
46	0	0	5	1	0	0	0	756	510	0	0	0	0
47	0	0	2	1	0	0	1	0	1614	0	0	0	0
48	19	22	139	54	7	0	109	74	0	0	0	0	0

APPENDIX II (contd.)

NODE	40	41	42	43	44	45	46	47	48	49	50	51	52
49	26	193	66	0	0	0	0	0	0	0	58	0	0
50	70	15	3	0	0	14	0	0	0	159	0	3	7
51	14	0	0	0	0	6	0	0	0	0	18	0	5
52	22	0	45	24	0	72	0	0	0	0	27	16	0
53	31	0	0	0	0	54	0	0	0	0	39	37	76
54	19	27	0	0	0	0	0	0	262	0	0	0	0
55	7	0	690	84	0	396	0	0	0	0	9	5	6
56	9	7	45	0	0	682	0	0	0	1	14	6	6
57	41	0	6	2	0	16	0	0	0	0	52	1348	1284
58	1	0	54	5	0	1344	44	32	22	0	2	0	0
59	37	0	3	1	0	110	588	1489	144	0	48	0	0
60	0	28	3	0	0	0	0	0	0	1366	29	5	0
61	0	0	0	0	0	0	0	0	0	0	0	66	0
62	0	7	102	37	0	113	0	0	0	0	3	3	31
63	0	115	531	32	0	361	0	0	0	19	65	37	0
64	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0
66	3	78	39	22	0	52	0	0	0	0	0	0	0
67	0	2	0	0	0	0	0	0	0	0	0	0	0
68	0	178	83	32	0	49	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	141	94	0	189	0	0	0	0	0	0	0
73	1	0	1	1	0	2	0	0	0	0	0	0	0
74	0	0	141	94	0	280	0	0	0	0	0	0	0
75	0	9	16	10	0	22	0	0	0	0	0	0	0
76	3	0	16	6	0	137	484	721	159	0	5	0	0
77	0	0	19	6	1	10	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0	0	0	0	0	0
79	1	0	0	0	0	1	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0	0	0	0	0	0
82	81	88	0	0	0	2	0	0	0	0	10	0	3
83	0	0	0	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0	0
86	1	11	0	0	0	0	0	0	0	0	0	0	0
87	1	2	0	0	0	0	0	0	0	0	0	0	0
88	2	65	7	0	0	36	0	7	0	0	0	0	0
89	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	3	0	0	0	3	0	0	0	0	0	0	0
91	0	0	0	0	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0
93	0	2	0	0	0	2	0	0	0	0	0	0	0
94	0	0	0	0	0	0	0	0	0	0	0	0	0
95	0	0	11	3	0	6	0	0	0	0	0	0	0
96	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	40	41	42	43	44	45	46	47	48	49	50	51	52
97	0	0	0	0	0	0	0	0	0	0	0	0	1
98	0	0	0	0	0	0	0	0	0	0	0	0	0
99	0	0	0	0	0	6	0	0	0	0	0	3	0
100	0	0	0	0	0	0	0	0	0	0	0	0	0
101	0	0	0	0	0	0	0	0	0	0	0	0	0
102	0	0	0	0	0	0	0	0	0	0	0	0	0
103	0	0	0	0	0	0	0	0	0	0	0	989	0
104	0	0	0	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0	0	0
106	24	1	0	0	0	0	0	0	0	14	68	0	0
107	0	0	0	0	0	0	0	0	0	0	0	3	0
108	0	0	0	0	0	0	0	0	0	0	0	5	0
109	13	0	0	0	0	16	0	0	0	0	16	9	167
110	0	0	0	0	0	6	0	0	0	0	0	71	0
111	0	0	0	0	0	0	0	0	0	0	0	0	0
112	7	0	0	0	0	94	0	0	0	0	10	6	6
113	0	0	0	0	0	0	0	0	0	0	0	0	0
114	0	0	0	0	0	37	68	91	16	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0	0	0	0	0
117	328	460	0	0	0	0	0	0	1974	0	0	0	0
118	0	0	0	0	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	0	0	31	0	0	0	0	0	0	0
121	0	0	0	0	0	15	0	0	0	0	0	0	0
122	7	24	0	0	0	20	0	0	0	0	0	0	0
123	0	0	0	0	0	92	0	0	0	0	0	0	0
124	0	0	0	0	0	0	0	0	0	0	0	0	0
125	0	0	0	0	0	0	0	0	0	0	0	0	0
126	0	0	0	0	0	0	0	0	0	0	0	0	0
127	0	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	0	0	0	0	0	0	0	0
130	0	0	1	0	0	0	0	0	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0	0	0	0	0
132	0	0	0	0	0	0	0	0	0	0	0	0	0
133	0	0	0	0	0	0	0	0	0	0	0	0	44
134	0	0	0	0	0	0	0	0	0	0	0	0	15
135	0	0	0	0	0	0	0	0	0	0	9	28	72
136	0	352	61	0	0	0	0	0	0	0	174	0	0
137	0	2	0	0	0	0	0	0	0	0	0	0	0
138	16	24	0	0	0	0	0	0	328	0	0	0	0
139	0	0	0	0	0	0	0	0	0	0	0	0	0
140	0	0	211	84	0	127	0	0	0	0	0	0	0
141	0	0	0	0	0	0	0	0	0	0	0	0	0
142	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	4351	9084	8983	2098	347	10173	1861	3731	5651	2524	3008	3513	2974

NODE	53	54	55	56	57	58	59	60	61	62	63	64	65
1	344	375	409	492	501	470	304	780	0	759	317	611	52
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	36	36
4	538	6087	478	616	1216	513	78	55	131	1121	378	122	122
5	328	74	7	22	547	20	0	1033	0	50	14	279	325
6	0	0	0	0	0	0	0	61	6	0	0	217	442
7	0	0	2	2	50	57	35	0	9	83	37	0	0
8	0	5	9	7	114	61	300	0	20	81	39	0	0
9	0	2	80	101	20	58	0	0	3	128	32	0	0
10	3177	1541	20	54	6329	33	0	89	369	149	35	83	45
11	93	0	3	25	170	80	0	243	0	16	0	93	0
12	48	0	11	0	88	0	0	178	0	46	0	128	27
13	0	0	0	0	0	2	2	0	0	5	1	0	0
14	0	0	0	0	0	5	3	0	0	7	2	0	0
15	0	0	0	0	0	2	2	0	0	5	1	0	0
16	0	0	0	0	0	3	2	0	0	5	2	0	0
17	339	408	187	258	100	49	68	128	42	128	57	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	11	5	0	0	642	0
20	1817	0	5	9	292	5	7	0	0	0	0	0	0
21	0	0	0	0	0	0	7	0	0	0	0	0	0
22	40	0	0	0	37	0	0	0	0	0	0	0	0
23	36	0	31	41	9	3	5	15	5	20	9	0	0
24	243	0	96	131	19	11	16	31	10	78	33	0	0
25	1	32	0	0	1	0	0	0	0	14	7	0	0
26	0	0	2	2	53	20	3	0	9	27	14	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	180	228	0	145	63	0	0	349	91	0	0
31	0	0	0	0	0	0	0	0	0	3	0	0	0
32	0	0	0	0	0	37	31	9	3	87	27	0	0
33	0	0	1	0	0	0	0	20	2	6	0	464	54
34	0	29	0	0	0	0	0	29	13	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0
39	14	0	7	11	6	2	3	0	0	0	0	0	0
40	10	18	5	7	3	1	2	58	0	0	0	0	0
41	0	33	0	6	0	0	0	1258	0	7	3	0	0
42	0	0	811	1075	9	677	20	6	0	1353	439	0	0
43	0	0	75	0	3	28	11	0	0	692	68	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0
45	110	0	618	378	16	169	78	0	0	3764	832	0	0
46	0	0	0	0	0	2	18	0	0	0	0	0	0
47	0	0	0	0	0	1	84	0	0	0	0	0	0
48	0	250	0	0	0	78	84	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	53	54	55	56	57	58	59	60	61	62	63	64	65
49	0	0	0	53	0	0	0	111	0	39	32	0	0
50	15	0	9	15	6	2	3	1601	7	2	2	0	0
51	14	0	7	10	5	0	0	33	2646	6	2	0	0
52	536	0	10	13	141	0	0	0	0	61	0	0	0
53	0	0	52	70	439	10	15	78	26	31	13	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0
55	27	0	0	501	9	104	19	10	2	283	50	0	0
56	32	0	2271	0	13	37	46	15	3	594	367	0	0
57	1929	0	7	13	0	7	10	0	1138	7	0	0	0
58	5	0	100	85	5	0	124	0	0	490	254	0	0
59	87	0	48	76	96	81	0	0	0	49	14	0	0
60	19	0	9	15	0	0	0	0	48	19	10	0	0
61	6	0	2	5	357	0	0	41	0	6	2	0	0
62	14	0	2433	15	75	27	7	16	3	0	5612	0	0
63	136	0	67	192	14	243	28	184	37	643	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0	62
65	0	0	0	0	0	0	0	0	0	0	0	462	0
66	1	0	0	0	1	6	5	0	0	55	10	0	0
67	0	0	0	0	0	0	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0	0	0	66	41	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	189	0	0	0
73	0	0	0	0	0	0	0	0	0	2	0	0	0
74	0	0	0	0	0	68	31	0	0	292	0	0	0
75	0	0	0	0	0	2	1	0	0	24	2	0	0
76	9	1	5	7	10	114	1898	0	0	136	65	0	0
77	1	46	0	0	1	0	1	0	0	14	7	0	0
78	0	0	0	0	0	0	0	0	0	0	0	0	0
79	0	0	0	0	0	0	0	0	0	1	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0	0	0	0	0	0
82	9	0	0	0	9	2	0	24	10	2	2	0	0
83	0	0	0	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	0	0	0	0	0
87	0	0	0	0	0	0	0	0	0	0	0	0	0
88	0	0	5	3	0	27	10	0	0	36	27	0	0
89	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	2	0	0	0	3	2	0	0
91	0	0	0	0	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0
93	0	0	0	0	0	1	0	0	0	2	1	0	0
94	0	0	0	0	0	0	0	0	0	0	0	0	0
95	0	0	0	0	0	0	0	0	0	9	5	0	0
96	65	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	53	54	55	56	57	58	59	60	61	62	63	64	65
97	63	0	0	0	1	0	0	0	0	0	0	0	0
98	0	0	0	0	0	0	0	0	0	0	0	0	0
99	0	0	0	0	27	3	0	0	3	5	1	0	0
100	0	0	0	0	0	0	0	0	0	0	0	0	0
101	0	0	0	0	0	0	0	0	0	0	0	0	0
102	0	0	0	0	0	0	0	0	0	0	0	0	0
103	0	0	0	0	3	0	0	0	878	0	0	0	0
104	0	0	0	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0	0	0
106	0	0	0	0	0	0	0	107	0	0	0	0	0
107	15	0	6	9	0	0	0	13	3	13	5	0	0
108	124	0	6	9	162	0	0	15	5	11	5	0	0
109	16	0	10	13	302	0	0	0	0	0	0	0	0
110	0	0	0	0	396	3	0	0	71	6	1	0	0
111	0	0	0	0	0	0	0	0	0	0	0	0	0
112	32	0	93	122	11	10	15	11	3	61	27	0	0
113	0	0	0	0	0	0	0	0	0	0	0	0	0
114	0	0	0	0	0	27	189	0	0	37	16	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0	0	0	0	0
117	0	1028	0	0	0	0	0	0	0	0	0	0	0
118	0	236	0	0	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	1	0	0	0	24	14	0	0	36	1	0	0
121	0	0	0	0	0	10	6	0	0	16	0	0	0
122	0	0	0	0	0	15	0	0	0	18	15	0	0
123	0	0	0	0	0	68	31	0	0	102	0	0	0
124	0	0	0	0	0	0	0	0	0	0	0	0	0
125	0	0	0	0	0	0	0	0	0	0	0	0	0
126	0	0	0	0	0	0	0	0	0	0	0	0	0
127	0	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	0	0	0	0	0	0	0	0
130	1388	0	5	5	1164	0	0	0	0	7	3	0	0
131	0	0	0	0	0	0	0	0	0	0	0	0	0
132	0	16	0	0	0	0	0	0	0	0	0	0	0
133	110	0	0	0	132	0	0	0	0	0	0	0	0
134	163	0	0	0	191	0	0	0	0	0	0	0	0
135	0	0	0	0	263	0	0	22	9	0	0	0	0
136	0	0	0	45	0	0	0	321	54	68	45	0	0
137	0	0	0	0	0	0	0	0	0	0	0	0	0
138	0	146	0	0	0	0	0	0	0	0	0	0	0
139	0	0	0	0	0	0	0	0	0	0	0	262	19
140	0	0	41	0	0	0	0	0	0	170	0	0	0
141	0	0	0	0	0	0	0	0	0	0	0	0	0
142	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	11954	10328	8223	4742	13411	3425	3679	6606	5573	12594	9077	3399	1184

APPENDIX II (contd.)

NODE	66	67	68	69	70	71	72	73	74	75	76	77	78
1	10728	440	672	247	102	72	136	166	62	1862	881	1443	139
2	5	0	0	0	57	85	2	1	0	0	0	0	85
3	10	0	0	0	61	91	5	2	0	0	0	0	91
4	2535	33	70	0	146	208	72	58	0	156	583	678	208
5	165	74	98	35	9	5	0	0	0	35	0	0	5
6	16	14	28	0	0	0	0	0	0	0	0	0	0
7	102	0	0	0	5	2	0	0	1	50	85	19	2
8	0	0	0	0	0	0	0	0	6	0	1137	15	0
9	10	0	0	0	0	0	1	1	18	6	40	0	0
10	14	196	236	153	7	5	0	0	0	7	0	2	5
11	162	61	72	42	10	6	0	0	0	24	0	0	6
12	193	117	136	85	53	35	28	19	0	33	0	0	35
13	33	0	0	0	0	0	0	0	0	16	3	3	0
14	3	0	0	0	0	0	0	0	0	1	6	1	0
15	1	0	0	0	15	7	0	0	0	0	3	57	7
16	1	0	0	0	0	0	0	0	0	0	3	24	0
17	1092	91	114	0	0	0	0	16	0	183	100	0	0
18	3	0	0	0	0	0	0	0	0	0	0	0	0
19	11	0	0	0	0	0	0	3	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	11	0	0
21	74	14	14	0	0	0	0	0	0	39	19	66	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	7	2	0
24	1	0	0	0	0	0	0	0	0	1	26	23	0
25	111	1	3	0	0	0	1	1	0	11	0	705	0
26	133	29	35	0	15	7	0	0	1	0	44	0	7
27	14	0	0	0	0	0	0	0	0	0	0	0	0
28	13	0	0	0	0	0	0	0	0	0	0	0	0
29	0	54	76	0	0	0	0	0	0	0	0	0	0
30	54	0	0	0	0	0	9	9	50	36	180	0	0
31	13	0	0	0	0	0	1007	1028	0	5	0	0	0
32	410	3499	4543	728	755	487	1142	1215	6	171	44	9	900
33	44	114	145	83	81	54	24	20	0	0	0	0	54
34	53	2	3	0	0	0	0	1	0	6	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	231	0	0	0	0	0	0	0	0	0	0	0	0
39	40	2	2	0	0	0	0	1	0	5	6	0	0
40	2	0	0	0	0	0	0	1	0	0	3	0	0
41	62	3	5	0	0	0	0	0	0	9	0	0	0
42	28	0	2	0	0	0	2	2	54	16	71	2	0
43	14	0	0	0	0	0	1	1	55	9	41	0	0
44	0	0	0	0	0	0	0	0	0	0	0	11	0
45	32	0	1	0	0	0	2	2	327	18	105	1	0
46	0	0	0	0	0	0	0	0	0	0	44	0	0
47	0	0	0	0	0	0	0	0	0	0	226	0	0
48	0	0	0	0	0	0	0	0	0	0	248	0	0

APPENDIX II (contd.)

NODE	66	67	68	69	70	71	72	73	74	75	76	77	78
49	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	6	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0
53	16	0	0	0	0	0	0	0	0	0	22	11	0
54	0	0	0	0	0	0	0	0	0	0	1	9	0
55	0	0	0	0	0	0	0	0	0	0	27	0	0
56	0	0	0	0	0	0	0	0	0	0	67	0	0
57	0	0	0	0	0	0	0	0	0	0	15	0	0
58	5	0	0	0	0	0	0	0	27	2	234	0	0
59	5	0	0	0	0	0	0	0	6	2	135	9	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0
62	31	0	1	0	0	0	2	2	2876	18	6	1	0
63	223	15	49	0	0	0	0	0	0	111	113	49	0
64	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0
66	0	434	544	54	104	79	126	141	7	1907	7	522	144
67	145	0	4734	635	0	0	0	0	0	52	0	0	0
68	941	271	0	3533	0	0	0	0	0	295	0	49	0
69	310	248	379	0	0	0	0	0	0	206	0	0	0
70	122	0	0	0	0	2109	0	0	0	37	0	0	14
71	559	0	0	0	96	0	0	0	0	139	0	0	122
72	289	0	0	0	0	0	0	61	46	189	0	0	0
73	11	0	0	0	0	0	2299	0	0	3	0	0	0
74	284	0	0	0	0	0	46	46	0	189	31	0	0
75	214	410	588	102	76	57	137	156	3	0	2	5	106
76	7	0	0	0	0	0	0	0	7	3	0	1	0
77	114	0	2	0	0	0	1	1	0	9	5	0	0
78	15	0	0	0	1069	832	0	0	0	2	0	0	0
79	74	0	0	0	0	0	0	0	0	0	1	0	0
80	0	0	0	0	62	93	0	0	0	0	0	0	93
81	106	18	26	0	0	0	0	0	0	0	0	0	0
82	997	29	42	0	0	0	0	16	0	0	6	39	0
83	0	3	5	0	0	0	0	0	0	0	0	0	0
84	13	3	6	0	0	0	0	0	0	0	0	0	0
85	180	74	104	0	0	0	0	0	0	0	0	0	0
86	633	0	0	0	0	0	0	0	0	0	0	52	0
87	170	0	0	0	0	0	0	0	0	0	0	14	0
88	247	0	0	0	0	0	0	0	0	0	74	0	0
89	18	0	0	0	0	0	0	0	0	0	0	0	0
90	91	0	0	0	0	0	0	0	0	0	6	1	0
91	1379	0	0	0	0	0	0	0	0	0	0	163	0
92	283	0	0	0	0	0	0	0	0	0	0	0	0
93	91	0	0	0	0	0	0	0	0	0	3	1	0
94	66	11	14	0	5	2	0	0	0	0	0	0	2
95	330	179	362	110	20	10	15	31	0	405	0	6	10
96	0	0	0	0	0	0	0	0	0	0	0	2	0

APPENDIX II (contd.)

NODE	66	67	68	69	70	71	72	73	74	75	76	77	78
97	0	0	0	0	0	0	0	0	0	0	0	0	0
98	206	0	0	0	0	0	0	0	0	0	0	0	0
99	61	9	11	0	0	0	0	0	0	0	6	0	0
100	62	0	0	0	0	0	0	0	0	0	0	0	0
101	83	0	0	0	0	0	0	0	0	0	0	0	0
102	105	0	0	0	0	0	0	0	0	0	0	0	0
103	0	0	0	0	0	0	0	0	0	0	0	0	0
104	336	0	0	0	0	0	0	0	0	0	0	0	0
105	110	0	0	0	0	0	0	0	0	0	0	0	0
106	0	0	0	0	0	0	0	0	0	0	0	0	0
107	0	0	0	0	0	0	0	0	0	0	0	1	0
108	0	0	0	0	0	0	0	0	0	0	0	196	0
109	0	0	0	0	0	0	0	0	0	0	0	0	0
110	44	9	11	0	0	0	0	0	0	0	6	0	0
111	24	0	0	0	0	0	0	0	0	0	0	0	0
112	0	0	0	0	0	0	0	0	0	0	22	0	0
113	0	0	0	0	0	0	0	0	0	0	0	0	0
114	0	0	0	0	0	0	0	0	2	0	683	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0	0	0	0	0
117	0	0	0	0	0	0	0	0	0	0	18	178	0
118	0	0	0	0	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	0	0	0	0	0	0
120	28	5	6	0	0	0	0	0	14	0	27	0	0
121	18	2	3	0	0	0	0	0	6	0	13	0	0
122	92	44	53	0	0	0	0	0	0	0	111	0	0
123	1	0	0	0	0	0	0	0	37	0	33	0	0
124	149	0	0	0	0	0	0	0	0	0	92	0	0
125	201	0	0	0	0	0	0	0	0	0	55	0	0
126	0	0	0	0	0	0	0	0	0	0	0	0	0
127	0	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	0	0	0	0	0	0	0	0
130	0	0	0	0	0	0	0	0	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0	0	0	0	0
132	0	0	0	0	0	0	0	0	0	0	18	0	0
133	0	0	0	0	0	0	0	0	0	0	0	0	0
134	0	0	0	0	0	0	0	0	0	0	0	0	0
135	0	0	0	0	0	0	0	0	0	0	0	0	0
136	0	0	0	0	0	0	0	0	0	0	0	0	0
137	261	0	0	0	0	0	0	0	0	0	0	11	0
138	0	0	0	0	0	0	0	0	0	0	0	5	0
139	0	0	0	0	0	0	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0	0	0	0	0
141	440	0	0	0	0	0	37	53	0	150	0	66	0
142	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	26508	6508	13195	5807	2748	4246	5095	3054	3611	6418	5761	4452	2035

APPENDIX II (contd.)

NODE	79	80	81	82	83	84	85	86	87	88	89	90	91
1	28	9	79	1045	31	380	130	1621	577	165	109	679	133
2	0	57	0	2	0	0	0	1	0	0	0	1	0
3	0	61	0	5	0	0	0	3	0	0	1	3	0
4	102	132	71	598	23	244	98	726	211	490	210	475	185
5	0	0	16	11	0	0	0	18	6	78	0	7	0
6	0	0	19	28	0	7	0	7	10	74	0	0	0
7	40	0	0	107	45	325	76	0	0	76	31	98	0
8	36	0	0	98	29	284	65	0	0	70	28	88	0
9	2	0	0	7	1	23	9	0	0	5	2	5	0
10	0	0	27	0	0	0	0	0	0	114	0	0	0
11	0	0	0	44	0	10	0	37	27	7	0	7	0
12	0	0	0	52	0	13	0	40	29	6	0	7	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	22	0	0	341	0	156	0	188	115	31	0	70	0
18	0	0	0	2	0	5	0	1	1	0	0	0	0
19	5	0	0	28	0	3	0	3	3	6	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0
22	5	0	0	1	0	0	0	0	0	5	0	10	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	7	0	0	0	0	0	0	3	0	0
25	0	0	0	3	0	0	0	27	10	0	1	2	9
26	113	0	0	287	260	1173	343	0	0	206	80	258	0
27	3	0	0	7	302	169	52	5	0	3	0	5	0
28	0	0	0	757	0	68	22	2	1	0	0	0	0
29	0	0	32	197	36	49	49	0	0	0	0	0	0
30	0	0	0	0	3	50	5	0	0	0	0	0	0
31	7	0	0	20	0	0	0	0	0	9	0	0	0
32	23	0	176	273	15	20	20	0	0	600	0	0	0
33	5	0	27	62	0	0	0	14	0	107	0	0	0
34	2	0	0	22	0	0	0	10	5	6	0	3	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	40	0	0	0	107	91	62	0	0	0
39	1	0	0	11	0	0	0	7	3	5	0	2	0
40	1	0	0	7	0	0	0	1	1	2	0	0	0
41	0	0	0	7	0	0	0	11	3	3	0	5	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0
45	1	0	0	2	0	0	0	0	0	2	0	2	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0
47	9	0	0	22	0	0	0	0	0	15	7	14	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	79	80	81	82	83	84	85	86	87	88	89	90	91
49	0	3	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	1	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0
53	0	0	0	9	0	0	0	7	0	0	0	6	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0
55	2	0	0	9	0	0	0	0	0	3	0	6	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0	0	0	0
58	1	0	0	2	0	0	0	0	0	1	0	2	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	2	0	0	0	0	0	0	0	0	0
61	0	0	0	1	0	0	0	0	0	0	0	0	0
62	1	0	0	2	0	0	0	0	0	1	0	2	0
63	22	0	0	49	0	0	0	0	0	36	0	45	0
64	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0
66	10	0	115	1069	0	84	32	2369	756	171	161	694	349
67	0	0	3	20	3	5	5	0	0	0	0	0	0
68	0	0	46	250	46	62	62	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0
71	0	37	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0
73	9	0	0	27	0	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	0	0	11	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0
76	2	0	0	6	0	0	0	0	0	5	0	6	0
77	0	0	0	3	0	0	0	29	11	0	1	2	9
78	0	1	0	0	0	0	0	0	0	0	0	0	0
79	0	0	0	157	0	0	0	0	0	1246	18	28	0
80	0	0	0	0	0	0	0	0	0	0	0	0	0
81	0	0	0	53	3	5	5	36	0	182	0	0	0
82	904	0	24	0	157	210	210	338	143	1114	52	240	0
83	0	0	1	11	0	131	131	0	0	0	0	0	0
84	0	0	2	14	2	0	3330	5	0	0	0	0	0
85	0	0	44	239	44	247	0	41	0	0	0	0	0
86	0	0	413	796	0	89	28	0	945	187	78	426	512
87	0	0	0	642	0	0	0	67	0	215	0	0	639
88	137	0	53	358	0	0	0	114	65	0	79	258	0
89	96	0	0	1006	0	0	0	2	0	137	0	7	0
90	196	0	0	1994	0	0	0	23	0	306	383	0	0
91	0	0	0	0	0	0	0	549	222	0	0	0	0
92	0	0	0	0	0	0	0	113	89	0	0	0	55
93	88	0	0	787	0	0	0	20	0	135	167	941	0
94	9	0	0	20	0	16	9	0	0	0	9	10	0
95	14	0	0	35	0	24	14	0	0	0	14	16	0
96	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	79	80	81	82	83	84	85	86	87	88	89	90	91
97	0	0	0	0	0	0	0	0	0	0	0	0	0
98	0	0	0	113	0	0	0	81	0	0	40	81	0
99	2	0	0	24	0	1810	471	0	0	2	9	5	0
100	0	0	0	0	0	2355	412	0	0	0	0	0	0
101	0	0	0	0	0	247	0	41	0	0	0	0	0
102	1	0	0	9	0	257	154	0	0	1	2	1	0
103	0	0	0	0	0	0	0	0	0	0	0	0	0
104	0	0	0	0	32	0	0	83	0	0	0	150	0
105	0	0	0	0	0	0	0	0	0	0	0	0	0
106	0	0	0	0	0	0	0	0	0	0	0	0	0
107	0	0	0	0	0	0	0	0	0	0	0	0	0
108	0	0	0	0	0	0	0	0	0	0	0	0	0
109	0	0	0	0	0	0	0	0	0	0	0	0	0
110	2	0	0	7	0	0	0	0	0	2	0	5	0
111	0	0	0	0	0	0	0	0	0	0	0	0	0
112	0	0	0	0	0	0	0	0	0	0	0	0	0
113	0	0	0	0	0	0	0	0	0	0	0	0	0
114	1	0	0	5	0	0	0	0	0	2	0	2	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0	0	0	0	0
117	0	0	0	0	0	0	0	0	0	0	0	0	0
118	0	0	0	0	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	0	0	0	0	0	0
120	2	0	0	5	0	0	0	0	0	2	0	3	0
121	1	0	0	3	0	0	0	0	0	1	0	2	0
122	0	0	0	0	0	0	0	0	0	0	0	0	0
123	0	0	0	1	0	0	0	0	0	0	0	1	0
124	16	0	0	36	0	0	0	0	0	16	0	24	0
125	0	0	0	0	0	0	0	0	0	0	0	0	0
126	0	0	0	0	0	0	0	0	0	0	0	0	0
127	0	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	0	0	0	0	0	0	0	0
130	0	0	0	0	0	0	0	0	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0	0	0	0	0
132	0	0	0	0	0	0	0	0	0	0	0	0	0
133	0	0	0	0	0	0	0	0	0	0	0	0	0
134	0	0	0	0	0	0	0	0	0	0	0	0	0
135	0	0	5	37	0	0	0	0	0	0	0	0	0
136	0	0	0	1	0	0	0	0	0	0	0	0	0
137	16	0	16	37	0	0	0	107	26	2051	0	26	2102
138	0	0	0	0	0	0	0	0	0	0	0	0	0
139	0	0	0	0	0	0	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0	0	0	0	0
141	0	0	0	0	0	0	0	0	0	0	0	0	0
142	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	1937	300	1169	11933	1032	8521	5732	6854	3350	7974	1485	4730	3993

APPENDIX II (contd.)

NODE	92	93	94	95	96	97	98	99	100	101	102	103	104
1	44	611	530	2342	124	0	23	1835	292	102	159	22	187
2	0	1	0	0	0	0	0	0	0	0	0	0	0
3	0	2	0	0	0	0	0	0	0	0	0	0	0
4	0	370	0	52	469	20	28	1365	257	48	44	131	16
5	0	5	0	0	0	0	0	1	0	0	0	32	0
6	0	0	0	0	0	0	0	26	9	5	0	0	0
7	0	75	7	18	0	0	0	1697	395	127	46	9	33
8	0	68	0	0	1	0	0	1580	345	114	27	20	22
9	0	5	0	0	0	0	0	115	23	3	3	3	1
10	0	0	0	0	0	13	0	57	0	0	0	369	0
11	0	6	0	0	0	0	0	54	11	6	0	11	0
12	0	6	0	0	0	0	0	48	15	9	0	6	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	1	0	0	0	0	0	0	0	0	0
15	0	0	20	49	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	53	0	0	0	0	0	540	182	104	0	0	0
18	0	0	0	0	0	0	0	10	5	2	0	0	0
19	0	0	0	0	0	0	0	15	5	2	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	10	0	0	2	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	1745	0	0	10	0	0	2	0	0
25	0	1	0	14	9	0	0	0	0	0	0	0	0
26	0	205	91	217	0	0	0	6059	1368	384	642	9	195
27	0	1	1	3	0	0	0	3	0	45	1120	0	226
28	0	0	0	0	0	0	0	0	0	18	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	267	67	27	2	0	2
31	0	0	0	1	0	0	0	0	0	0	0	0	0
32	0	0	13	115	0	0	0	18	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	2	0	0	0	0	0	9	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	1	0	0	0	0	0	6	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	3	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	10	0	0	0	0	0	0	0	0	0
43	0	0	0	3	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	1	0	5	0	0	0	2	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	11	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	92	93	94	95	96	97	98	99	100	101	102	103	104
49	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	2	0	0	0	0	0
52	0	0	0	0	0	18	0	0	0	0	0	0	0
53	0	6	0	0	15	14	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0
55	0	9	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	11	0	19	0	0	0	1222	0
58	0	1	0	0	0	0	0	2	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	260	0	0	0	65	0
62	0	1	0	6	0	0	0	2	0	0	0	0	0
63	0	27	0	166	0	0	0	27	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0
66	33	578	153	755	0	0	27	192	10	16	42	0	120
67	0	0	1	18	0	0	0	3	0	0	0	0	0
68	0	0	45	299	0	0	0	91	0	0	0	0	0
69	0	0	0	387	0	0	0	0	0	0	0	0	0
70	0	0	0	1	0	0	0	0	0	0	0	0	0
71	0	0	19	49	0	0	0	0	0	0	0	0	0
72	0	0	0	1	0	0	0	0	0	0	0	0	0
73	0	0	0	2	0	0	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0	35	0	0	0	0	0
75	0	0	0	52	0	0	0	0	0	0	0	0	0
76	0	3	0	0	0	0	0	3	0	0	0	0	0
77	0	1	0	10	13	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0	0	0	0	0	0
79	0	24	22	55	0	0	0	1	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0	0	0	0	0	0
82	0	176	1	5	0	0	1359	15	0	0	3	0	0
83	0	0	0	0	0	0	0	0	0	0	0	0	698
84	0	0	1	2	0	0	0	20	7	4711	1	0	0
85	0	0	48	97	0	0	0	261	91	0	39	0	0
86	33	336	0	0	0	0	20	0	0	23	0	0	63
87	59	0	0	0	0	0	0	0	0	0	0	0	0
88	0	202	0	0	2	0	0	1	0	0	0	0	0
89	0	5	0	2	0	0	57	0	0	0	0	0	0
90	0	44	1	2	0	0	59	3	0	0	1	0	991
91	932	0	0	0	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0
93	0	0	2	9	0	0	24	0	0	0	81	0	200
94	0	84	0	94	0	0	0	140	9	0	68	0	0
95	0	75	240	0	0	0	0	239	14	0	67	0	0
96	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	92	93	94	95	96	97	98	99	100	101	102	103	104
97	0	0	0	0	0	0	0	0	0	0	0	0	0
98	0	61	0	0	0	0	0	0	0	0	0	0	0
99	0	0	26	67	0	0	0	0	3005	652	360	3	0
100	0	0	20	49	0	0	0	93	0	1058	0	0	0
101	0	0	0	0	0	0	0	417	234	0	0	0	0
102	0	27	41	93	0	0	0	5	0	0	0	0	0
103	0	0	0	0	0	0	0	2	0	0	0	0	0
104	0	133	0	0	0	0	0	0	0	0	0	0	0
105	0	0	22	44	0	0	0	275	61	0	16	0	0
106	0	0	0	0	0	0	0	0	0	0	0	0	0
107	0	0	0	0	0	0	0	0	0	0	0	0	0
108	0	0	0	0	65	0	0	0	0	0	0	0	0
109	0	0	0	0	0	0	0	0	0	0	0	0	0
110	0	0	20	58	0	0	0	616	0	0	1	71	0
111	0	0	7	19	0	0	0	275	0	0	0	0	0
112	0	0	0	0	0	0	0	0	0	0	0	0	0
113	0	0	0	0	0	0	0	0	0	0	0	0	0
114	0	1	0	0	0	0	0	2	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0	0	0	0	0
117	0	0	0	0	0	0	0	0	0	0	0	0	0
118	0	0	0	0	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	13	33	0	0	0	42	0	0	1	0	0
121	0	0	6	19	0	0	0	49	0	0	0	0	0
122	0	0	72	175	0	0	0	265	0	0	0	0	0
123	0	0	0	1	0	0	0	36	0	0	0	0	0
124	0	0	46	111	0	0	0	200	0	0	7	0	0
125	0	0	62	150	0	0	0	135	0	0	0	0	0
126	0	0	0	0	0	0	0	0	0	0	0	0	0
127	0	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	0	0	0	0	0	0	0	0
130	0	0	0	0	0	0	0	0	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0	0	0	0	0
132	0	0	0	0	0	0	0	0	0	0	0	0	0
133	0	0	0	0	0	0	0	0	0	0	0	0	0
134	0	0	0	0	0	0	0	0	0	0	0	0	0
135	0	0	0	0	0	0	0	0	0	0	0	11	0
136	0	0	0	0	0	0	0	0	0	0	0	0	0
137	198	0	0	0	0	0	0	23	0	0	7	0	0
138	0	0	0	0	0	0	0	0	0	0	0	0	0
139	0	0	0	0	0	0	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0	0	0	0	0
141	0	0	0	93	0	0	0	0	0	0	0	0	0
142	0	0	0	0	0	0	0	71	0	0	0	0	0
TOTAL	1299	3231	1530	5754	2445	76	1597	17539	6405	7456	2739	1984	2754

APPENDIX II (contd.)

NODE	105	106	107	108	109	110	111	112	113	114	115	116	117
1	96	89	6	124	0	1556	153	0	0	436	0	0	247
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	29	0	828	555	0	1430	52	737	293	226	0	0	5359
5	0	0	5	0	0	1	0	0	0	0	0	0	97
6	0	53	0	0	0	15	0	0	0	0	0	0	0
7	58	0	5	0	0	1614	87	0	0	24	0	0	0
8	50	0	1	0	0	1631	83	0	0	614	0	0	3
9	1	0	0	0	0	123	3	0	0	26	0	0	1
10	0	0	11	224	348	130	0	0	0	0	0	0	1339
11	0	22	3	0	0	50	0	0	0	0	0	0	0
12	0	20	2	0	0	32	0	0	0	0	0	0	0
13	0	0	1	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	28	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	42	42	66	339	0	187	0	0	0	0	544
18	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	10	0	0	0	0	0	0	0
20	0	0	0	391	0	0	0	5	0	0	0	0	0
21	0	0	153	0	0	0	0	0	0	9	0	0	0
22	0	0	0	1069	0	0	0	0	0	0	0	0	0
23	0	0	1324	5	6	0	0	31	0	0	0	0	0
24	0	0	915	1697	10	0	0	1079	391	0	0	0	0
25	0	0	2	9	0	0	0	0	0	0	0	0	20
26	271	0	0	0	0	4849	227	0	0	26	0	0	0
27	0	0	0	0	0	3	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0
30	10	0	0	0	0	237	22	0	0	88	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	1	0	0	26	0	0	0	0	0	0	0
33	0	11	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	13	0	0	0	0	0	0	40
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	5	10	0	7	0	0	0	0	0
40	0	0	0	0	3	0	0	5	0	0	0	0	24
41	0	19	0	0	0	0	0	0	0	0	0	0	45
42	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	63	3	0	67	0	2	0	0	0
46	0	0	0	0	0	0	0	0	0	23	0	0	0
47	0	0	0	0	0	0	0	0	0	104	0	0	0
48	0	0	0	0	0	0	0	0	0	62	0	0	166

APPENDIX II (contd.)

NODE	105	106	107	108	109	110	111	112	113	114	115	116	117
49	0	16	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	6	0	0	9	0	0	0	0	0
51	0	0	1	1	3	6	0	7	0	0	0	0	0
52	0	0	0	0	990	0	0	10	0	0	0	0	0
53	0	0	10	725	19	0	0	52	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	4321
55	0	0	2	2	5	0	0	14	0	0	0	0	0
56	0	0	3	3	5	0	0	18	0	0	0	0	0
57	0	0	0	136	425	44	0	7	0	0	0	0	0
58	0	0	0	0	0	3	0	2	0	1	0	0	0
59	0	0	3	0	0	0	0	48	0	14	0	0	0
60	0	23	5	5	0	0	0	9	0	0	0	0	0
61	0	0	1	1	0	585	0	2	0	0	0	0	0
62	0	0	3	3	0	3	0	6	0	2	0	0	0
63	0	0	37	37	0	37	0	62	0	42	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0
66	14	0	1	0	0	123	2	0	0	0	0	0	0
67	0	0	0	0	0	6	0	0	0	0	0	0	0
68	0	0	14	0	0	127	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0	0
74	0	0	0	0	0	48	0	0	0	20	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0
76	0	0	0	0	0	6	0	5	0	42	0	0	0
77	0	0	3	13	0	0	0	0	0	1	0	0	31
78	0	0	0	0	0	0	0	0	0	0	0	0	0
79	0	0	0	0	0	1	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0	0	0	0	0	0
82	0	0	0	0	0	6	0	0	0	3	0	0	0
83	0	0	0	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	0	0	0	0	0
87	0	0	0	0	0	0	0	0	0	0	0	0	0
88	0	0	0	0	0	1	0	0	0	39	0	0	0
89	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	5	0	0	0	2	0	0	0
91	0	0	0	0	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0
93	0	0	0	0	0	0	0	0	0	1	0	0	0
94	6	0	0	0	0	91	1	0	0	0	0	0	0
95	9	0	0	0	0	167	2	0	0	0	0	0	0
96	0	0	0	2249	0	0	0	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	105	106	107	108	109	110	111	112	113	114	115	116	117
97	0	0	0	0	0	0	0	0	0	0	0	0	0
98	0	0	0	0	0	0	0	0	0	0	0	0	0
99	848	0	0	0	0	5913	279	0	0	3	0	0	0
100	1231	0	0	0	0	0	0	0	0	0	0	0	0
101	0	0	0	0	0	0	0	0	0	0	0	0	0
102	310	0	0	0	0	1	0	0	0	0	0	0	0
103	0	0	0	0	0	6	0	0	0	0	0	0	0
104	0	0	0	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0	0	0
106	0	0	0	0	0	0	0	0	0	0	0	0	0
107	0	0	0	3	0	0	0	6	0	0	0	0	0
108	0	0	3	0	0	0	0	6	0	0	0	0	0
109	0	0	0	0	0	0	0	10	0	0	0	0	0
110	0	0	0	0	0	0	4966	0	0	3	0	0	0
111	0	0	0	0	0	611	0	0	0	0	0	0	0
112	0	0	3	3	5	0	0	0	859	0	0	0	0
113	0	0	0	0	0	0	0	5	0	0	0	0	0
114	0	0	0	0	0	3	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0	0	0	0	0
117	0	0	0	0	0	0	0	0	0	10	0	0	0
118	0	0	0	0	0	0	0	0	0	0	0	0	156
119	0	0	54	0	0	0	0	205	81	0	0	0	0
120	0	0	0	0	0	581	0	0	0	15	0	0	0
121	0	0	0	0	0	166	0	0	0	7	0	0	0
122	0	0	0	0	0	351	0	0	0	70	0	0	0
123	0	0	0	0	0	54	0	0	0	22	0	0	0
124	0	0	0	0	0	598	0	0	0	61	0	0	0
125	0	0	0	0	0	690	0	0	0	36	0	0	0
126	0	0	0	0	0	0	0	0	0	0	0	0	0
127	0	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	0	0	0	0	0	0	0	0
130	0	0	0	0	0	0	0	0	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0	0	0	0	0
132	0	0	0	0	0	0	0	0	0	10	0	0	10
133	0	0	0	0	0	0	0	0	0	0	0	0	0
134	0	0	0	0	0	0	0	0	0	0	0	0	0
135	0	0	0	0	72	0	0	0	0	0	0	0	0
136	0	0	0	0	0	0	0	0	0	0	0	0	0
137	0	0	0	0	0	28	0	0	0	0	0	0	0
138	0	0	0	0	0	0	0	0	0	0	0	0	8463
139	0	0	0	0	0	0	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0	0	0	0	0
141	0	0	0	0	0	0	0	0	0	0	0	0	0
142	0	0	0	0	0	88	35	0	0	0	0	0	0
TOTAL	2933	253	3470	7297	2031	22421	5912	2601	1624	2044	0	0	20866

APPENDIX II (contd.)

NODE	118	119	120	121	122	123	124	125	126	127	128	129	130
1	1	0	573	361	163	52	59	88	0	0	0	0	75
2	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0
4	265	435	665	549	83	117	127	35	0	0	0	0	3
5	0	0	1	1	0	0	0	0	0	0	0	0	89
6	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	149	120	35	19	16	9	0	0	0	0	0
8	0	0	468	317	87	72	46	40	0	0	0	0	0
9	0	0	63	46	5	10	9	3	0	0	0	0	0
10	106	0	0	0	0	0	0	0	0	0	0	0	1679
11	0	0	1	1	0	0	0	0	0	0	0	0	24
12	0	0	2	1	0	0	0	0	0	0	0	0	11
13	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	28	27	10	7	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	817
21	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	213	0	0	0	0	0	0	0	0	0	0	0
24	0	604	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	625	426	141	55	63	74	0	0	0	0	0
27	0	0	3	3	0	1	1	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	33	20	13	3	0	2	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	18	14	6	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	28	27	0	7	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	118	119	120	121	122	123	124	125	126	127	128	129	130
49	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	83
53	0	0	0	0	0	0	0	0	0	0	0	0	5487
54	254	0	1	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0
57	0	0	0	0	0	0	0	0	0	0	0	0	763
58	0	0	31	22	0	9	0	0	0	0	0	0	0
59	0	0	26	19	0	7	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	22	15	0	6	0	0	0	0	0	0	0
63	0	0	27	24	13	0	0	0	0	0	0	0	5
64	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0
66	0	0	88	50	15	6	13	16	0	0	0	0	0
67	0	0	3	2	1	0	0	0	0	0	0	0	0
68	0	0	91	72	36	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0	0	0	0	0	0	0
74	0	0	131	102	0	44	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	0	0	0
76	0	0	470	243	71	61	32	59	0	0	0	0	0
77	0	0	0	0	0	0	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0	0	0	0	0	0	0
79	0	0	1	1	0	0	0	0	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	0	0	0	0	0	0	0
82	0	0	6	6	0	2	1	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0	0
86	0	0	0	0	0	0	0	0	0	0	0	0	0
87	0	0	0	0	0	0	0	0	0	0	0	0	0
88	0	0	1	1	0	0	0	0	0	0	0	0	0
89	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	5	5	0	2	1	0	0	0	0	0	0
91	0	0	0	0	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0
93	0	0	0	0	0	0	0	0	0	0	0	0	0
94	0	0	66	37	13	3	7	11	0	0	0	0	0
95	0	0	123	71	24	6	14	20	0	0	0	0	0
96	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	118	119	120	121	122	123	124	125	126	127	128	129	130
97	0	0	0	0	0	0	0	0	0	0	0	0	0
98	0	0	0	0	0	0	0	0	0	0	0	0	0
99	0	0	629	384	122	54	58	89	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0	0	0
101	0	0	0	0	0	0	0	0	0	0	0	0	0
102	0	0	1	1	0	0	0	0	0	0	0	0	0
103	0	0	0	0	0	0	0	0	0	0	0	0	0
104	0	0	0	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0	0	0
106	0	0	0	0	0	0	0	0	0	0	0	0	0
107	0	852	0	0	0	0	0	0	0	0	0	0	0
108	0	0	0	0	0	0	0	0	0	0	0	0	0
109	0	0	0	0	0	0	0	0	0	0	0	0	0
110	0	0	2698	1314	289	171	310	526	0	0	0	0	0
111	0	0	0	0	0	0	0	0	0	0	0	0	0
112	0	859	0	0	0	0	0	0	0	0	0	0	0
113	0	1544	0	0	0	0	0	0	0	0	0	0	0
114	0	0	167	94	24	23	13	18	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0	0	0	0	0
117	1881	0	18	14	0	5	0	0	0	0	0	0	0
118	0	0	0	0	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	0	0	0	0	0	0	0
120	0	0	0	2821	742	478	423	2770	0	0	0	0	0
121	0	0	145	0	2778	1986	2028	0	0	0	0	0	0
122	0	0	366	325	0	14	0	0	0	0	0	0	0
123	0	0	136	109	422	0	1916	0	0	0	0	0	0
124	0	0	457	503	0	102	0	0	0	0	0	0	0
125	0	0	505	0	0	0	0	0	0	0	0	0	0
126	0	0	0	0	0	0	0	0	0	0	0	0	0
127	0	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	0	0	0	0	0	0	0	0
130	0	0	0	0	0	0	0	0	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0	0	0	0	0
132	0	0	18	14	113	5	0	0	0	0	0	0	0
133	0	0	0	0	0	0	0	0	0	0	0	0	32
134	0	0	0	0	0	0	0	0	0	0	0	0	67
135	0	0	0	0	0	0	0	0	0	0	0	0	0
136	0	0	0	0	0	0	0	0	0	0	0	0	0
137	0	0	28	28	0	14	7	0	0	0	0	0	0
138	309	0	0	0	0	0	0	0	0	0	0	0	0
139	0	0	0	0	0	0	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0	0	0	0	0
141	0	0	0	0	0	0	0	0	0	0	0	0	0
142	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	2816	4507	8917	8180	5206	3341	5144	3760	0	0	0	0	9135

APPENDIX II (contd.)

NODE	131	132	133	134	135	136	137	138	139	140	141	142
1	0	0	52	9	22	217	451	244	712	26	68	13
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	3	0	0	0	24	461	4169	0	26	29	0
5	0	0	75	5	32	339	68	72	41	27	0	0
6	0	0	0	0	3	6	63	0	308	0	0	0
7	0	1	0	0	0	0	0	0	0	0	0	6
8	0	7	0	0	0	0	0	2	0	0	0	5
9	0	1	0	0	0	0	0	0	0	0	0	0
10	0	0	0	39	66	35	100	963	83	27	0	0
11	0	0	19	1	11	68	7	0	156	28	0	0
12	0	0	7	1	6	48	6	0	158	622	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	3	408	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	2	5	0	0	959	0	0	0
20	0	0	0	22	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	10	20	0	0	1	0
26	0	3	0	0	0	0	0	0	0	0	0	14
27	0	0	0	0	0	0	3	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	2
31	0	0	0	0	0	0	0	0	0	0	230	0
32	0	0	0	0	2	3	499	0	0	0	418	0
33	0	0	0	0	1	2	88	0	464	2522	0	0
34	0	0	0	0	7	13	2	29	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0
36	0	0	0	0	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	0	0
38	0	0	0	0	0	0	62	0	0	0	0	0
39	0	0	0	0	0	0	2	0	0	0	0	0
40	0	0	0	0	0	0	0	18	0	0	0	0
41	0	0	0	0	0	435	3	33	0	0	0	0
42	0	0	0	0	0	2	0	0	0	3	0	0
43	0	0	0	0	0	0	0	0	0	1	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	1	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	124	0	0	0	0

APPENDIX II (contd.)

JNDF	131	132	133	134	135	136	137	138	139	140	141	142
49	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	5	483	0	0	0	0	0	0
51	0	0	0	0	507	0	0	0	0	0	0	0
52	0	0	61	9	102	0	0	0	0	0	0	0
53	0	0	517	209	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	3824	0	0	0	0
55	0	0	0	0	0	0	0	0	0	41	0	0
56	0	0	0	0	0	1	0	0	0	0	0	0
57	0	0	92	31	159	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0	0	0
59	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	28	3837	0	0	0	0	0	0
61	0	0	0	0	146	0	0	0	0	0	0	0
62	0	0	0	0	0	2	0	0	0	1	0	0
63	0	7	0	0	0	31	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	2347	0	0	0
65	0	0	0	0	0	0	0	0	66	0	0	0
66	0	0	0	0	0	0	703	0	0	0	68	0
67	0	0	0	0	0	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	0	0	1482	0
73	0	0	0	0	0	0	0	0	0	0	583	0
74	0	0	0	0	0	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0	0	0	0	63	0
76	0	9	0	0	0	0	0	0	0	0	0	0
77	0	0	0	0	0	0	11	31	0	0	1	0
78	0	0	0	0	0	0	0	0	0	0	0	0
79	0	0	0	0	0	0	36	0	0	0	0	0
80	0	0	0	0	0	0	0	0	0	0	0	0
81	0	0	0	0	0	0	302	0	0	0	0	0
82	0	0	0	0	6	10	33	0	0	0	0	0
83	0	0	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0
86	0	0	0	0	0	0	995	0	0	0	0	0
87	0	0	0	0	0	0	1015	0	0	0	0	0
88	0	0	0	0	0	0	358	0	0	0	0	0
89	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	10	0	0	0	0	0
91	0	0	0	0	0	0	222	0	0	0	0	0
92	0	0	0	0	0	0	89	0	0	0	0	0
93	0	0	0	0	0	0	0	0	0	0	0	0
94	0	0	0	0	0	0	0	0	0	0	0	0
95	0	0	0	0	0	0	0	0	0	0	15	0
96	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX II (contd.)

NODE	131	132	133	134	135	136	137	138	139	140	141	142
97	0	0	0	0	0	0	0	0	0	0	0	0
98	0	0	0	0	0	0	0	0	0	0	0	0
99	0	3	0	0	0	0	3	0	0	0	0	23
100	0	0	0	0	0	0	0	0	0	0	0	0
101	0	0	0	0	0	0	0	0	0	0	0	0
102	0	0	0	0	0	0	1	0	0	0	0	0
103	0	0	0	0	44	0	0	0	0	0	0	0
104	0	0	0	0	0	0	0	0	0	0	0	0
105	0	0	0	0	0	0	0	0	0	0	0	0
106	0	0	0	0	0	0	0	0	0	0	0	0
107	0	0	0	0	0	0	0	0	0	0	0	0
108	0	0	0	0	0	0	0	0	0	0	0	0
109	0	0	0	0	616	0	0	0	0	0	0	0
110	0	11	0	0	0	0	3	0	0	0	0	137
111	0	0	0	0	0	0	0	0	0	0	0	825
112	0	0	0	0	0	0	0	0	0	0	0	0
113	0	0	0	0	0	0	0	0	0	0	0	0
114	0	2	0	0	0	0	0	0	0	0	0	0
115	0	0	0	0	0	0	0	0	0	0	0	0
116	0	0	0	0	0	0	0	0	0	0	0	0
117	0	6	0	0	0	0	0	822	0	0	0	0
118	0	0	0	0	0	0	0	115	0	0	0	0
119	0	0	0	0	0	0	0	0	0	0	0	0
120	0	41	0	0	0	0	2	0	0	0	0	0
121	0	122	0	0	0	0	1	0	0	0	0	0
122	0	7	0	0	0	0	0	0	0	0	0	0
123	0	79	0	0	0	0	0	0	0	0	0	0
124	0	0	0	0	0	0	19	0	0	0	0	0
125	0	0	0	0	0	0	0	0	0	0	0	0
126	0	0	0	0	0	0	0	0	0	0	0	0
127	0	0	0	0	0	0	0	0	0	0	0	0
128	0	0	0	0	0	0	0	0	0	0	0	0
129	0	0	0	0	0	0	0	0	0	0	0	0
130	0	4	825	825	0	0	0	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0	0	0	0
132	0	0	0	0	0	0	0	6	0	0	0	0
133	0	0	0	0	0	0	0	0	0	0	0	0
134	0	0	0	0	0	0	0	0	0	0	0	0
135	0	0	0	0	0	9	0	0	0	0	0	0
136	0	0	0	0	36	0	0	0	0	0	0	0
137	0	0	0	0	0	0	0	0	0	0	0	0
138	0	0	0	0	0	0	0	0	0	0	0	0
139	0	0	0	0	0	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0	0	0	0
141	0	0	0	0	0	0	0	0	0	0	0	0
142	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	302	1648	1151	1801	5570	5631	10880	5294	3325	2958	1025

APPENDIX III : A SET OF ROUTES GENERATED BY HEURISTIC PROCEDURE FOR AHMEDABAD BUS TRANSIT NETWORK

ROUTE NO.	ROUTE LENGTH	TRANSFER SAVED	NODES TOUCHED BY A ROUTE					
1	2.40	29	2	3	4	10		
2	2.20	8	3	4	10	57		
3	2.20	72	4	10	3	2		
4	2.00	67	4	3	10	57		
5	2.10	54	5	6	11	12		
6	2.10	18	11	5	41	106		
7	2.40	46	43	58	45	62		
8	2.50	49	58	43	45	62		
9	2.20	72	2	3	10	4		
10	2.10	43	5	11	41	106		
11	2.40	25	6	33	12			
12	2.40	15	11	6	33			
13	2.10	19	11	5	41	106		
14	2.80	6	11	6	106			
15	3.00	69	12	11	6	5	41	
16	2.50	25	14	7	8	114		
17	2.40	27	20	53	109	52		
18	2.40	28	20	53	97	52	109	
19	2.00	15	26	93	90			
20	2.40	64	53	96	22	108		
21	3.30	23	93	86	66	95		
22	2.90	42	93	96	75	95		
23	3.10	65	100	94	102	99	110	
24	2.70	89	1	13	66	95		
25	2.00	32	1	66	95			
26	2.40	34	2	3	10	5		
27	2.50	67	2	3	4	10	57	20
28	2.90	9	2	3	5	57		
29	2.00	36	2	3	4	10	57	
30	2.50	38	3	5	6	11		
31	2.20	37	3	10	5	11		
32	2.00	2	3	5	41			
33	3.00	130	4	3	10	57	5	
34	2.00	46	4	9	8			
35	2.80	50	4	77	8			
36	2.60	33	5	10	57	20		
37	2.00	20	7	14	15			
38	2.00	9	7	8	30			
39	3.00	43	7	8	9	30		
40	2.00	2	8	7	13			
41	2.60	7	8	25	13			
42	2.60	33	9	8	7	14		

CONTD....

APPENDIX III (contd.)

ROUTE NO.	ROUTE LENGTH	TRANSFER SAVED	NODES TOUCHED BY A ROUTE					
43	2.50	49	10	5	11	41		
44	2.70	84	13	66	95	75	86	
45	2.80	40	20	53	97	52	51	
46	2.00	5	27	28	29			
47	2.00	11	27	93	94			
48	2.60	67	32	75	95	66	86	
49	2.60	32	32	95	66	86		
50	2.50	35	32	95	75	86		
51	2.00	29	32	75	95	94		
52	2.50	40	41	11	5	57		
53	2.70	24	42	56	45			
54	2.60	39	43	45	62	56		
55	2.00	4	49	60	50			
56	3.60	73	56	62	45	43	58	
57	2.50	33	56	62	45	58		
58	2.00	8	61	60	136			
59	2.70	48	62	56	55	112		
60	2.60	85	66	75	95	32	81	
61	2.00	5	67	32	75			
62	2.60	40	75	95	66	86	81	
63	2.00	11	75	95	94	93		
64	3.30	52	75	95	66	86	93	
65	2.00	11	86	66	95	94		
66	2.10	17	87	86	66	95		
67	2.30	17	93	27	26	99		
68	2.90	11	93	27	102	99		
69	2.00	36	96	22	108	107		
70	2.60	128	1	2	3	4	42	
71	3.20	172	1	2	3	10	4	
72	2.90	87	1	2	3	5		
73	3.40	131	1	2	3	10	5	
74	2.10	76	1	12	11	5		
75	2.30	75	1	12	11	6		
76	2.50	37	1	13	7			
77	2.80	68	1	30	8	7		
78	2.60	47	1	25	8			
79	2.10	42	1	30	8			
80	2.40	23	1	30	9			
81	2.40	62	1	2	3	10		
82	2.40	66	1	12	11	41		
83	3.80	183	1	12	11	6	5	41
84	3.00	128	1	13	66	95	75	

contd.....

APPENDIX III (contd.)

ROUTE NO.	ROUTE LENGTH	TRANSFER SAVED	NODES TOUCHED BY A ROUTE					
85	2.20	28	1	25	77			
86	3.20	74	1	13	66	86		
87	3.90	178	1	13	66	95	75	96
88	2.50	18	1	66	86			
89	2.70	58	1	66	95	94		
90	3.40	115	1	13	66	95	94	
91	2.70	89	1	13	66	95		
92	2.00	32	1	66	95			
93	2.70	79	4	9	8	7		
94	2.00	46	4	9	8			
95	2.80	50	4	77	8			
96	2.10	25	4	77	25			
97	2.80	57	4	3	5	41		
98	2.70	46	4	10	5	41		
99	3.20	57	4	9	42	43		
100	2.20	17	4	42	43			
101	2.90	14	4	42	56			
102	2.60	19	5	41	34			
103	2.50	14	6	19	34			
104	3.20	29	6	5	41	34		
105	2.50	40	7	8	14	15		
106	2.00	20	7	14	15			
107	2.80	52	7	26	99	110		
108	2.60	48	8	7	26	99		
109	3.20	83	10	3	2	1	12	
110	3.10	86	10	5	6	11	12	
111	2.30	41	10	5	11	12		
112	2.10	69	10	57	20	53		
113	2.80	115	10	57	52	97	53	
114	2.30	16	11	6	19			
115	2.90	46	11	12	33	19		
116	2.60	19	11	41	34			
117	3.40	70	17	39	34	41		
118	2.40	34	17	40	41			
119	2.20	16	18	35	36			
120	2.50	45	21	107	23	24		
121	2.10	15	24	23	107			
122	2.60	31	24	22	108			
123	2.90	62	24	96	22	108		
124	2.70	79	4	9	8	7		
125	3.00	38	30	8	9	42		
126	2.60	22	30	9	42			

contd.......

APPENDIX III (contd.)

ROUTE NO.	ROUTE LENGTH	TRANSFER SAVED	NODES	TOUCHED	BY A	ROUTE			
127	2.20	18	31	73	72				
128	2.50	29	32	67	68				
129	2.20	20	32	31	73				
130	2.60	50	32	81	137	88			
131	2.40	7	12	33	65				
132	2.40	2	12	1	66				
133	3.10	56	12	1	13	66			
134	2.40	54	42	43	45	62			
135	3.30	92	42	43	58	45	62		
136	2.40	10	45	62	63				
137	2.10	14	53	130	133				
138	2.50	54	57	20	53	130			
139	2.50	18	57	53	130				
140	2.90	76	66	95	94	93	90		
141	2.60	20	66	86	93				
142	2.10	49	66	95	94	93			
143	3.40	69	66	95	86	66	93		
144	3.40	125	66	75	95	32	81	137	
145	2.70	48	66	86	81	137			
146	2.50	44	66	86	87	137			
147	2.50	10	73	72	141				
148	2.10	16	87	137	91				
149	2.30	37	99	100	84	101			
150	2.50	48	99	102	84	101			
151	2.50	17	99	100	105				
152	2.40	26	99	102	105				
153	2.80	7	99	110	120				
154	2.90	14	110	120	121				
155	2.90	19	112	113	119				
156	3.00	37	121	132	122				
157	3.00	57	1	12	33	19			
158	3.90	64	1	12	33	32			
159	3.30	116	1	66	95	75	32		
160	3.30	73	1	66	95	32			
161	4.00	132	1	13	65	95	32		
162	4.00	125	1	2	3	4	10	57	
163	3.90	106	1	2	3	5	57		
164	3.00	83	1	2	3	10	57		
165	3.10	98	1	12	11	5	57		
166	3.30	43	1	66	86	87			
167	4.70	205	1	13	66	95	75	86	87
168	5.60	210	1	13	66	95	75	86	93

contd.....

APPENDIX III (contd.)

ROUTE NO.	ROUTE LENGTH	TRANSFER SAVED	NODES	TOUCHED	BY	A	ROUTE		
169	4.40	155	1	13	66	95	94	93	
170	3.40	123	4	3	2	1	12		
171	4.00	136	4	3	5	6	11	12	
172	3.20	91	4	3	5	11	12		
173	3.20	19	4	24	23				
174	3.90	120	4	9	8	7	26		
175	3.10	59	4	42	43	45			
176	4.00	55	4	42	56	45			
177	3.20	50	4	42	43	58			
178	3.50	90	4	9	8	114	76		
179	3.10	16	4	24	112				
180	3.20	26	4	54	138				
181	3.40	22	5	50	60				
182	3.50	13	6	19	18				
183	3.50	99	8	7	26	99	110		
184	3.10	113	10	57	20	53	130		
185	3.10	16	12	33	32				
186	3.60	13	12	33	140				
187	3.20	23	19	64	139				
188	3.70	48	24	112	113	119			
189	3.50	39	26	99	110	120			
190	4.50	15	46	47	48				
191	3.40	27	54	138	117				
192	4.70	9	67	68	69				
193	3.10	47	86	91	137	91			
194	3.40	11	110	120	125				
195	3.00	37	121	132	122				
196	5.80	228	1	12	11	41	34	39	17
197	4.80	177	1	12	11	41	40	17	
198	5.80	134	1	12	11	6	19	18	
199	5.00	79	1	12	33	19	18		
200	3.90	117	1	2	3	4	24		
201	5.50	140	1	2	3	5	41	34	
202	4.80	144	1	12	11	6	19	34	
203	4.10	95	1	12	11	41	34		
204	4.00	90	1	12	33	19	34		
205	4.80	113	1	12	33	19	34	39	
206	6.30	138	1	2	3	5	50	60	
207	4.90	87	1	12	33	19	64		
208	4.50	131	1	66	95	94	93	90	
209	4.40	103	1	13	7	26	99		
210	5.20	148	1	25	8	7	26	99	

contd.......

APPENDIX III (contd.)

ROUTE NO.	ROUTE LENGTH	TRANSFER SAVED	NODES TOUCHED BY A ROUTE										
211	7.50	318	1	13	66	95	75	86	93	26	99		
212	4.80	96	4	24	23	107	21						
213	4.50	87	4	3	5	41	34						
214	4.20	123	4	3	2	1	66						
215	4.60	148	4	9	8	7	26	99					
216	4.40	44	4	24	23	107							
217	4.90	64	4	24	22	108							
218	5.20	100	4	24	96	22	108						
219	5.30	138	10	5	41	34	39	17					
220	4.30	92	10	5	41	40	17						
221	4.00	42	10	4	54	138							
222	6.40	242	12	11	6	5	41	34	39	17			
223	5.40	188	12	11	6	5	41	40	17				
224	4.20	130	66	75	95	32	67	68					
225	4.20	132	66	95	94	93	90	82					
226	4.00	51	120	121	132	122							
227	5.80	134	1	12	11	6	19	18					
228	5.00	79	1	12	33	19	18						
229	7.80	168	1	2	3	5	41	34	18				
230	5.70	197	1	2	3	4	42	43	45				
231	6.60	197	1	2	3	4	42	56	45				
232	6.40	130	1	12	33	32	67	68					
233	5.80	193	1	66	75	95	32	67	68				
234	5.80	201	1	66	95	94	93	90	82				
235	6.10	207	1	25	8	7	26	99	110				
236	5.30	154	1	13	7	26	99	110					
237	7.40	339	4	3	2	1	12	11	41	40	17		
238	5.10	154	4	10	5	41	40	17					
239	8.00	476	4	3	2	1	12	11	6	5	41	40	17
240	6.20	209	4	3	5	41	34	39	17				
241	5.20	160	4	3	5	41	40	17					
242	5.90	259	4	3	2	1	66	95	75	32			
243	5.90	214	4	3	2	1	66	95	32				
244	5.50	275	4	3	2	1	13	66	95	32			
245	6.50	213	4	3	2	1	12	33	32				
246	5.80	205	4	3	2	1	13	66	86				
247	6.50	309	4	3	2	1	13	66	95	75	86		
248	5.10	147	4	3	2	1	66	86					
249	5.50	205	4	9	8	7	26	99	110				
250	5.60	80	4	54	138	117							
251	7.40	231	4	9	8	7	26	99	110	120			
252	6.00	128	4	9	8	114	76	120					

contd....

APPENDIX III (contd.)

ROUTE NO.	ROUTE LENGTH	TRANSFER SAVED	NODES TOUCHED BY A ROUTE
253	5.70	159	10 3 2 1 66 95 32
254	6.40	217	10 3 2 1 13 66 95 32
255	6.30	171	10 3 2 1 12 33 32
256	5.70	48	32 67 68 69
257	10.00	434	1 2 3 4 9 8 7 26 99 110 120
258	8.60	303	1 2 3 4 9 8 114 76 120
259	7.20	176	1 13 7 26 99 110 120
260	6.30	126	1 13 7 26 110 120
261	6.20	144	1 12 33 19 64 139
262	9.40	342	4 3 2 1 66 95 94 93 90 82
263	7.40	231	4 9 8 7 26 99 110 120
264	6.00	129	4 9 8 114 76 120
265	8.40	266	4 9 8 7 26 99 110 120 121
266	6.40	103	10 4 54 138 117
267	5.40	231	1 13 7 8 9 4
268	4.20	211	4 10 5 11 12 1
269	4.75	218	1 12 11 5 10 4 24
270	4.90	172	4 9 7 13 1
271	8.40	322	4 9 8 7 26 27 28 29 31 32
272	5.55	139	32 33 6 5 10 4
273	8.75	269	4 10 5 6 33 32 81 137 88
274	9.50	400	79 98 79 82 89 90 93 26 7 8 9 4
275	9.33	374	4 9 8 7 26 93 90 89 82 79 88
276	8.75	269	88 137 81 32 33 6 5 10 4
277	7.05	251	4 9 8 7 26 99 100 84 101
278	7.05	206	4 9 8 7 26 99 100 105
279	7.10	247	4 9 8 7 26 99 100 84 85
280	6.00	236	1 30 8 7 26 99 110 111
281	7.75	262	1 30 8 7 26 99 110 111 142
282	6.25	228	1 66 95 94 26 99 110 111
283	12.30	549	17 39 34 19 6 11 12 1 30 8 7 26 99 110
284	5.50	173	1 66 95 94 26 99 100
285	6.70	230	4 9 8 7 26 99 110 111
286	10.90	358	110 99 26 7 8 9 4 10 57 103 51 61
287	5.45	172	4 9 8 7 26 99 100
288	9.15	261	1 66 95 94 26 99 110 120 125
289	9.20	263	1 30 8 7 26 99 110 120 125
290	10.75	752	17 40 39 34 41 5 11 12 1 30 8 7 26 99 110
			120 121 123 122
291	12.50	326	1 66 95 94 26 99 110 120 121 123 124
292	10.50	243	1 30 8 114 76 120 121 123 122
293	11.95	309	4 9 8 7 26 99 110 120 121 122
294	9.25	266	4 9 8 7 26 99 110 120 121

contd.

APPENDIX III (contd.)

ROUTE NO.	ROUTE LENGTH	TRANSFER SAVED	NODES TOUCHED BY A ROUTE
295	11.95	352	4 9 8 7 26 99 110 120 121 123 124
296	11.95	315	4 9 8 7 26 99 110 120 121 124
297	6.80	144	4 9 8 114 76 120 125
298	9.70	239	4 9 8 114 76 120 121 123 124
299	9.75	194	4 9 8 114 76 120 121 122
300	3.90	20	99 110 120 125
301	13.20	199	124 123 121 120 110 99 102 27 90 82 79 88 137
302	3.40	11	110 120 125
303	14.00	228	68 67 32 95 94 26 99 110 120 121 122
304	14.70	329	123 121 120 110 99 26 7 8 114 76 58 45 62 74
305	9.50	108	123 121 120 59 58 45 62 74
306	16.11	396	122 132 121 120 110 99 26 7 8 114 76 58 45 62 63
307	4.50	95	15 14 8 25 1
308	3.70	96	4 9 8 14 15
309	5.50	168	16 15 14 7 8 77 4
310	9.34	144	71 70 78 32 95 94 26 7 14 15
311	10.10	238	1 30 8 114 76 59 46 47 48
312	7.50	157	1 30 8 114 76 59 47
313	5.15	144	1 30 8 114 76 59 46
314	5.65	201	1 30 8 114 76 59 46 47
315	10.20	243	4 42 43 58 76 59 46 47 48
316	10.16	208	59 76 114 8 77 4 24 23 107 21
317	7.80	227	1 30 9 42 58 45 56 55
318	5.50	135	1 30 9 42 56 55
319	6.65	214	1 30 9 42 58 45 62 63
320	7.20	130	11 5 10 4 42 58 45
321	6.55	120	4 42 58 45 62 63
322	10.40	264	63 62 55 56 42 4 10 57 20 53 130
323	11.14	334	140 33 12 11 5 10 4 42 43 45 62 55
324	6.40	130	11 5 10 4 42 56 45
325	3.35	51	4 42 56 55
326	10.15	234	88 79 82 90 93 26 7 8 9 42 56 55
327	9.45	206	1 25 77 4 54 138 117
328	10.40	362	1 12 11 5 10 4 54 138 117 118
329	11.00	139	10 4 54 138 117 48
330	4.05	42	10 4 54 138
331	5.55	103	10 4 54 138 117
332	7.00	135	10 4 54 138 117 118
333	15.90	282	117 138 54 4 9 8 114 76 120 121 123 132
334	9.45	268	1 13 7 8 9 4 24 22
335	7.35	172	22 53 57 10 5 11 12 1
336	8.25	241	1 12 11 5 10 57 53 22 108

contd.....

APPENDIX III (contd.)

ROUTE NO.	ROUTE LENGTH	TRANSFER SAVED	NODES TOUCHED BY A ROUTE												
337	9.45	268	22	24	4	9	8	7	13	1					
338	7.80	196	1	25	77	4	24	96	108						
339	6.75	101	4	24	112	113	119								
340	6.75	106	4	24	23	107	119								
341	5.67	51	4	24	96	53									
342	4.25	132	4	10	57	52	97	53							
343	5.65	51	53	96	24	4									
344	12.80	372	22	96	24	4	9	8	7	26	93	90	82	79	88
345	11.15	262	24	4	9	8	7	26	99	102	89	82			
346	10.35	229	1	12	11	5	57	52	53	130	133				
347	14.30	317	82	90	93	86	66	1	12	11	5	57	52	53	
348	6.85	208	1	25	77	4	10	57	52	53					
349	10.30	202	1	12	11	5	57	52	53	130	134				
350	5.65	134	10	57	20	53	130	134							
351	5.10	179	4	10	57	20	53	22	108						
352	5.30	71	10	57	52	109	135								
353	7.20	132	52	57	10	4	42	43	45	62					
354	2.85	43	10	57	52	109									
355	15.22	221	82	81	32	33	6	19	34	50	60	136	61	135	
356	6.65	227	1	12	11	5	41	50	60	136					
357	8.00	222	1	12	11	41	5	50	60	49					
358	6.95	175	1	12	11	6	106	50	60						
359	9.55	313	1	80	6	19	34	39	40	17	49				
360	9.10	192	1	12	33	41	106	40	60	49					
361	11.85	236	136	60	50	41	5	10	4	42	56	62	63		
362	11.35	235	49	60	50	41	5	10	4	42	56	62	63		
363	7.30	200	1	12	11	6	19	64	139						
364	8.40	252	1	12	11	6	19	34	18	35	36				
365	7.80	129	10	3	5	6	19	18	35	36					
366	8.75	28	1	12	33	140									
367	6.40	142	1	12	33	65	64	139							
368	6.40	101	1	12	33	64	139								
369	7.40	199	1	2	80	6	19	64	139						
370	6.50	75	10	5	6	19	64	139							
371	7.85	231	1	66	95	75	32	67	68	69					
372	7.85	189	1	66	95	75	32	67	68						
373	7.65	254	1	66	95	75	32	31	73	72	141				
374	10.00	169	10	5	11	12	33	32	67	68					
375	10.00	217	10	5	11	12	33	32	67	68	69				
376	6.70	145	1	66	96	87	137	91	92						
377	6.75	120	1	56	85	93	90	104							
378	12.20	312	1	30	8	7	26	99	110	120	121	122			

contd.....

APPENDIX III (contd.)

ROUTE NO.	ROUTE LENGTH	TRANSFER SAVED	NODES TOUCHED BY A ROUTE														
379	12.10	303	1	66	95	94	26	99	110	120	121	122					
380	10.00	198	1	30	8	114	76	120	121	122							
381	11.95	309	4	9	8	7	26	99	110	120	121	122					
382	6.45	35	110	120	121	124											
383	11.35	335	17	40	34	41	5	10	4	54	138	117					
384	7.00	135	10	4	54	138	117	118									
385	6.50	103	10	4	54	138	117										
386	6.10	101	4	24	112	113	119										
387	8.05	168	1	12	11	5	57	103	51	135							
388	3.55	113	10	57	20	53	130										
389	3.55	113	10	57	20	53	130										
390	6.60	201	1	12	11	5	41	50	60	49							
391	6.60	171	1	12	11	5	41	50	60	61							
392	6.60	227	1	12	11	5	41	50	60	136							
393	2.60	111	1	2	3	4											
394	3.55	124	1	2	3	5	6										
395	11.50	295	21	107	23	24	4	77	25	13	7	14	15				
396	8.80	252	1	12	11	6	19	34	18	35	36						
397	7.00	238	38	17	39	34	41	5	3	4							
398	6.10	211	17	39	40	41	5	3	4								
399	13.80	403	17	39	40	50	51	52	109	53	23	24	112	55	56	45	
400	15.70	449	17	39	40	50	57	20	53	23	24	112	55	56	45	58	76
			59														
401	15.50	379	17	60	61	51	53	108	107	23	24	112	55	56	62	63	
402	7.50	81	4	3	5	65	64										
403	4.27	84	1	13	14	15	16										
404	12.10	306	17	18	19	6	5	10	4	9	7	14	15				
405	7.50	232	38	17	39	40	41	5	10	4							
406	16.95	435	38	17	39	40	41	5	10	4	42	43	44	46	47	48	
407	9.00	170	49	18	34	19	6	5	10	4							
408	4.15	31	10	5	6	65											
409	8.85	171	1	66	75	32	67	68	69								
410	12.15	462	17	39	34	41	5	11	12	1	66	75	32	67	68		
411	6.50	154	1	66	75	32	78	70	71								
412	13.60	389	72	73	31	32	75	66	1	30	9	42	43	45	62	74	
413	4.25	80	1	66	75	32	67										
414	15.20	347	32	75	66	13	7	14	15	16	76	59	58	45	62	63	
415	11.20	352	4	77	25	1	66	75	32	31	73	72	141				
416	4.95	102	1	66	75	32	78	70									
417	14.80	524	68	57	32	75	66	1	12	11	5	10	4	24	23	107	21
418	4.70	96	4	24	23	107	21										
419	2.40	219	4	10	5	11	12	33	78	70	71						
420	8.10	197	68	67	32	33	6	5	10	4							

contd....

APPENDIX III (contd.)

ROUTE NO.	ROUTE LENGTH	TRANSFER SAVED	NODES TOUCHED BY A ROUTE														
421	14.30	528	68	67	32	75	95	66	1	25	77	4	42	43	45	62	63
422	5.80	174	1	25	77	4	42	43	44								
423	9.55	217	4	3	2	12	33	32	31	73	72						
424	6.50	148	4	3	2	12	33	32									
425	8.05	155	4	3	2	80	78	70	71								
426	10.15	180	68	67	32	81	29	82	83	84	85						
427	12.65	341	17	40	39	34	19	33	32	31	73	88	79	82			
428	4.05	81	1	66	86	81	137										
429	12.35	446	38	17	39	34	41	5	11	12	1	66	86	87	137	88	
430	4.95	106	1	66	86	81	137	88									
431	3.30	37	1	66	86	81											
432	9.40	257	4	77	25	1	66	86	87	137	91						
433	13.05	321	88	79	82	90	93	26	7	8	114	76	58	45	62	63	
434	12.60	294	88	79	82	89	90	93	26	7	8	114	76	59	47		
435	13.50	341	38	18	19	6	11	12	1	66	86	87	28	82			
436	13.50	412	17	18	19	6	11	12	1	66	86	87	28	82			
437	12.80	471	17	39	34	19	6	11	12	1	66	86	87	28	82		
438	13.50	471	17	40	34	19	6	11	12	1	66	86	87	28	82		
439	7.18	264	1	66	95	94	93	90	89	82	79						
440	7.75	129	82	28	86	66	1	12	33								
441	6.10	145	1	66	86	93	90	82									
442	9.85	339	4	77	25	1	66	86	93	90	89	82					
443	10.55	367	4	3	2	1	66	86	93	90	89	82	98				
444	12.50	463	17	39	34	41	5	11	12	1	66	86	93	90	82		
445	14.25	560	17	18	19	6	11	12	1	30	8	7	26	99	100	84	101
446	7.90	161	1	66	86	28	27	84	101								
447	7.90	159	1	66	86	28	27	84	85								
448	5.90	160	1	30	8	7	26	27	102								
449	7.65	206	1	30	8	7	26	27	83	104							
450	5.85	157	1	66	95	94	93	27	102								
451	7.30	256	1	30	8	7	26	99	100	84	85						
452	7.30	214	1	30	8	7	26	99	100	105							
453	7.20	267	1	66	95	94	26	99	102	84	85						
454	7.15	227	1	66	95	94	26	99	102	105							
455	5.70	161	4	9	8	7	26	27	102								
456	7.50	185	4	9	8	7	26	27	83	104							
457	3.60	85	53	52	57	10	4										